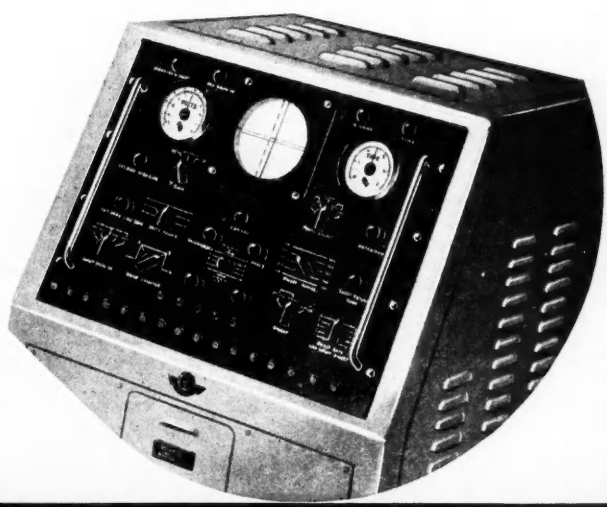
Electronic Engineering

TEST EQUIPMENT

OSCILLOSCOPE
TYPE WM. 5

This all purpose wide range measuring oscilloscope is a typical example of E.M.I. Test equipment for use in Laboratories, Development establishments and Testing departments concerned with electronic engineering.



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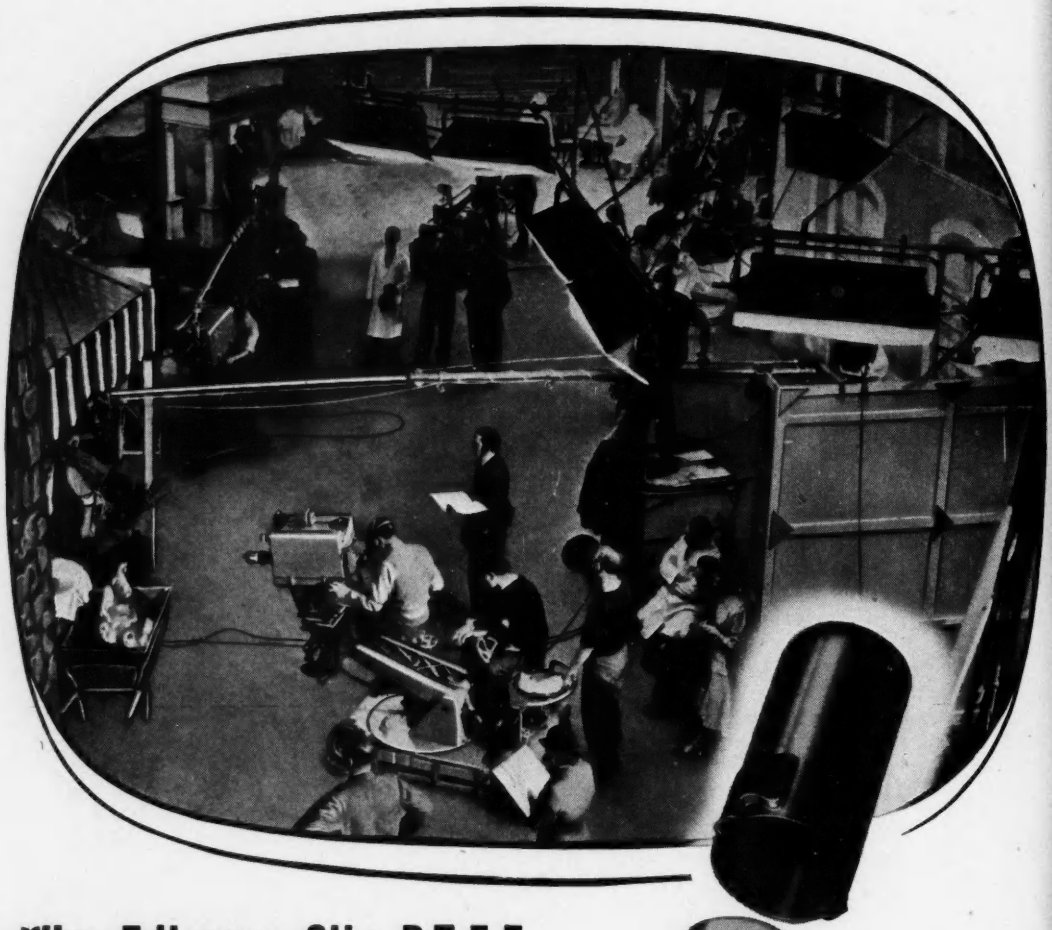

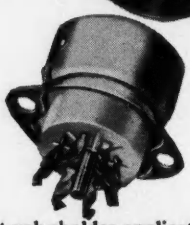

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1955

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements is 6d. per word. Minimum charge 12/-. Box number 2/- extra, except in the case of advertisements for "Situations Wanted," when it is free. Specially spaced advertisements per inch single column 42/6. A remittance must accompany the advertisement. Replies to Box numbers should be addressed to: "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

AIR MINISTRY requires Scientific Officers for Operational Research, in or near London, under direction of Scientific Adviser to Air Ministry. Qualifications: First or Second Class Honours Degree or equivalent, in Mathematics, Physics or Economics. Salary: (London) within range £492 10s. to £885. Provincial rates and rates for women somewhat lower. Posts unestablished, with possibilities of establishment, through the Civil Service Commission, for successful candidates whilst remaining under age 31. Application forms, quoting A.384/54A from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1. W 3185

AIR MINISTRY require Scientific Officer at R.A.F. Experimental Establishment in Norfolk, for development and adaptation of radio equipment pulse techniques including aerials, power supplies and displays. Quals.: 1st or 2nd class honours degree or equivalent in electrical engineering or physics with bias towards electronics. Previous experience of airborne radar systems would be an advantage. Salary according to age, and post graduate research experience in range £467 10s.-£845 (superannuable). Opportunities to compete for establishment may arise. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D163/5A. Closing date 10th June 1955. W 3151

APPLICATIONS invited for Electronics Technician. Duties include construction of equipment for wide range of researches. Previous experience an advantage but suitable applicants having just completed National Service considered. Salary in range £340-£480 plus London Weighting. Pension Scheme. Write to Professor A. R. Ubbelohde, Department of Chemical Engineering, Imperial College, S.W.7. W 3177

ASSISTANT ENGINEER (Telecommunications of Electronics) required for their London office by the Crown Agents for Overseas Governments and Administrations. Basic salary scale £650×£25 to £750×£30 to £960×£40 to £1,000 plus Extra Duty Allowance of approximately 8 per cent and a Pay Supplement of from £25 to £35 a year. The £650 minimum is linked to entry at age 25 and is subject to increase at the rate of one increment for each year above that age up to 34. Fully qualified officers at least 27 years old may be eligible for a special increase of £75 after two years' service. Engagement on unestablished terms with prospect of appointment to the established staff after five years' service and of promotion. Candidates should be between 25 and 35 years of age and have a degree in electrical engineering (Telecommunications and Electronics) or be a Graduate or Corporate Member of the Institution of Electrical Engineers. They should have had works experience with an established firm specializing in telecommunication and electronic equipment and have had subsequent operating or design experience on this type of equipment. Previous contract experience would be an advantage. The duties of the post will entail the purchase of all types of telecommunication, broadcasting and other electronic equipment including the preparation of detailed specifications to enable tenders to be invited, and adjudication thereon. Also, the preparation of reports giving advice to Administrations on problems connected with this type of equipment. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2/40772/EK. W 3190

BRITISH OVERSEAS AIRWAYS CORPORATION require Engineers for the overhaul and maintenance of flight simulators in their Central Training Unit, near London Airport. Applicants should have a thorough knowledge of electronic techniques; practical experience in the maintenance of analog computers, aircraft radio equipment and remote indicating system an advantage. Duties: 3-shift systems covering 24 hours per day; salary according to qualifications £640 to £756 12s. p.a. plus approx. £80 p.a. shift pay. Applications to be addressed to Staff Superintendent (Recruitment), B.O.A.C., London Airport, Hounslow, Middlesex. W 3228

BRITISH EMPIRE CANCER CAMPAIGN. Electronics Technician required to construct special apparatus for research and to assist with maintenance and operation of million volt electron accelerator. Age 22-35 preferred. Appointment will be either in the Technical Grade £470-£545, or in the Senior Technician Grade £570-£655, according to age and qualifications. Apply to Director, Research Unit in Radiobiology, Mount Vernon Hospital, Northwood, Middlesex. W 3146

CITY OF LIVERPOOL, Education Committee, Riversdale Technical College. Principal: A. R. Kinsman, B.Sc. (Eng), A.M.I.E.E., A.M.I.Mech.E. Applications are invited from suitably qualified persons for the undermentioned appointments (full-time). Grade A Assistant Teacher for Radio and Electrical Engineering. Industrial experience desirable. Grade B Assistant Teacher to assist in full-time P.M.G. Certificate and part-time Radio Servicing Courses. Industrial and/or Marine experience an advantage. Salaries in accordance with the Burnham Technical Scale, 1954. Further particulars and form of application (returnable as soon as possible) may be obtained from H. S. Magnay, M.A., Director of Education, 14 Sir Thomas Street, Liverpool, 1. Thomas Alker, Town Clerk and Clerk to the Local Education Authority. (JA.3890). W 3173

D.S.I.R. require Assistant Experimental Officers at Mechanical Engineering Research Laboratory, East Kilbride, near Glasgow, to assist in developing electronic devices, including pick-ups, amplifiers and associated equipment for precision measuring apparatus. Candidates must have two passes in G.C.E. at advanced level in mathematics and science. If over 22 would normally be expected to have pass degree H.N.C. or equivalent in engineering or physics. General knowledge or practical experience of electronics an advantage. Inclusive annual remuneration for 45½-hour week within range: (men) £297-£659, (women) £297-£570. East Kilbride is a new town with good housing prospects. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A 133/5A. W 3136

ELECTRICAL ENGINEER required at Ministry of Supply, Fighting Vehicles Research and Development Establishment, near Chertsey, Surrey for development of gun control equipment for fighting vehicles. The work involves experimental design of electrical and mechanical devices, and direction and supervision of work of this nature carried out in Industry for the Ministry. Quals.: 1st or 2nd class honours degree or equivalent qualification in Electrical Engineering. Working knowledge of electronics and servo mechanisms desirable. Salary within Senior Scientific Officer range £970-£1,125 (superannuable). Women somewhat less. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D 211/5A, closing date 10 June 1955. W 3263

ENGINEERS OR PHYSICISTS Atomic Energy of Canada Limited invites applications from engineers or physicists for electronics research and development with particular reference to circuits and systems in atomic energy research and the atomic power field. Applicants should have a first or second class honours degree. Post-graduate experience would be an advantage but is not essential. Salaries in the range $3,750 to $6,000 per annum, depending on qualifications and experience. It is hoped that interviews for applicants can be arranged in the U.K. State particulars including age, marital status, education and experience in first letter to File 4C, Atomic Energy of Canada Limited, Chalk River, Ontario. W 3174

INSTRUMENT ENGINEER required by the United Kingdom Atomic Energy Authority at Risley for design, adaption and selection of instruments for use on process plants. These include instruments for measuring temperature, pressures, pH flow and radio-activity, and equipment for analysing gases and liquids. Applicants should have served a recognized engineering apprenticeship with Corporate Membership of a Senior Engineering Institution, or equivalent. Experience in the field of instrument design is essential. Salary £695 (at age 25) to £1,065 p.a. The successful candidate will be required to join the Authority's contributory pension scheme. Send postcard for application form to the United Kingdom Atomic Energy Authority, Industrial Group Headquarters, Ris'ey, near Warrington. Reference 934 must be quoted. W 3231

MINISTRY OF SUPPLY requires Electronics Technician at Bickley, Kent, to assist calibration and repair of electronic test instruments. Quals.: British of British parents. Recognized engineering apprenticeship or equivalent in electronics. Knowledge high voltage measurements and calibration of meters at D.C. and power frequencies advantageous. O.N.C., appropriate City and Guilds certificates or equivalent desirable. Salary: Within £565 (age 26) to £695. Not established but opportunities to compete for establishment may arise. Apply any Employment Exchange quoting Order No. Westminster 3360. W 3194

MINISTRY OF SUPPLY requires Electronics Technicians at Farnborough, Hants (and possibly at Bickley, Kent later) to supervise, or assist in, scheduling of R.A.F. telecommunication equipment showing breakdown into sub assemblies and components; preparing lists of spares, connectors for aircraft installations; ensuring completeness of contractors drawings. Qualifications: British of British parents. Recognized engineering apprenticeship or equivalent in electronics. Must have long workshop experience radio/allied equipments, able interpret drawing, specifications, circuit diagrams. Knowledge component standardization and R.A.F. service requirements advantageous. O.N.C. or City and Guilds or equivalent desirable. Vacancies in two grades at salaries within £535 (age 26) to £772. Application forms from A.B. 1181, London Appointments Office, Ministry of Labour and National Service, 1-6 Tavistock Square, W.C.1. W 3184

PROFESSIONAL ENGINEERS required for a wide range of duties covering:— 1. Workshops. To control workshops making high precision mechanical, electromechanical and electronic devices and equipment. 2. Chemical Engineering. To lead or serve in project teams engaged on the design and development of chemical plant equipment. 3. Project Liaison and Planning. To co-ordinate the activities of several groups working on scientific and engineering aspects of weapons design and to maintain liaison between a number of groups covering the project. 4. Methods Engineers. To lead or to serve in a team working on the development of new methods, processes and techniques in mechanical engineering manufacture. 5. Planning of New Buildings and Services. To be responsible for the production of plans and specifications for new offices, laboratories and workshops, their associated plant and services, and the general supervision of construction. Applicants should have previous experience in one or more of the fields given above, have served a recognized engineering apprenticeship and be corporate members of one of the Institutions of Chemical, Civil, Electrical and Mechanical Engineers or possess equivalent qualifications. Salary: The salary scales are within the range of £695 to £1,620. Starting pay will be assessed according to age, qualifications and experience. Superannuation: The successful applicants will be required to join the Authority's contributory scheme. Housing: Housing accommodation will be available within a reasonable period for married officers who live outside the radius of the Establishment's transport facilities or alternatively the Authority may be able to assist successful applicants in the purchase of a house. During this period a lodging allowance may be payable. Applicants should state the type of post for which they wish to be considered and quote reference 645/WGE/42. Requests for application forms by Post Card to Senior Recruitment Officer, United Kingdom Atomic Energy Authority, Aldermaston, Berks. W 3229

OFFICIAL APPOINTMENTS (Cont'd.)

PHYSICIST or Electrical Engineer, young graduate (B.Sc.), required by small University Research Laboratory for construction and maintenance of electronic medical devices. Salary £500 to £850 p.a. according to qualifications and age; F.S.S.U. benefits. Vacancy in autumn. Application giving particulars to: Nuffield Department of Anaesthetics, Radcliffe Infirmary, Oxford. W 3255

POST OFFICE: Assistant Engineer. The Civil Service Commissioners announce an open competition commencing 16th August, 1955 for not less than 50 posts for men. Age at least 17½ and under 23½ on 1st March, 1955, with extension for service in H.M. Forces and, up to two years, for established civil service. Starting salary (London) according to age from £402 (at 18) up to £540 at age 25 or over on entry. Maximum £815. Somewhat lower in provinces. For particulars (including prospects) and application form write (preferably by post card) to Secretary, Civil Service Commission, Burlington Gardens, London. W.1, quoting No. 159/55. Application forms must be returned by 23rd June, 1955. W 3218

THE LONDON HOSPITAL MEDICAL COLLEGE, Turner Street, London. E.1, requires a Technician for the construction, testing and maintenance of electro-medical apparatus. O.N.C. or equivalent qualification desirable but not essential. Salary, according to age and experience, on the Whitley Scales for Medical Laboratory Staff. Applications, stating age, qualifications and experience, to the Secretary within 14 days. W 3175

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Aldermaston, Berks, requires an Experimental Officer to be responsible for the design of transformers, chokes and R.F. coils for electronic equipment for instrumentation and equipment design departments. The minimum qualification is H.S.C. (Science) or equivalent, but a H.N.C. in Electrical Engineering is desirable. Applicants should have experience of small power (less than ¼ kilowatt) transformer and choke design and R.F. and I.F. coil design with particular reference to service climatic conditions. A knowledge of pulse transformer design technique would be an advantage. Salary £775-£945 p.a. (male) minimum age 26. The successful applicant will be required to join the Authority's contributory superannuation scheme. Housing accommodation will be available within a reasonable period for married officers who live outside the radius of the Establishment's transport facilities or alternatively the Authority may be able to assist successful applicants in the purchase of a house. During this period lodging allowance may be payable. Requests for application forms by postcard to Senior Recruitment Officer, A.W.R.E., Aldermaston, Berks. Quote reference 646/WGE/42. W 3230

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Aldermaston, Berks, requires a number of Mechanical Design Engineers in the grade of Engineer III to assist in the design and development of prototype mechanical and electro-mechanical devices to meet scientist's requirements. Applicants should have served a recognized engineering apprenticeship and be corporate members of one of the Institutions of Mechanical or Electrical Engineers. Previous experience in the mechanical design field and of current Drawing Office and Workshop practice is desirable. For two of the posts a knowledge of vacuum techniques would be an advantage. Salary £695 (age 25) £1,065 p.a. (male). The successful applicants will be required to join the Authority's contributory superannuation scheme. Housing accommodation will be available within a reasonable period for married officers who live outside the radius of the Establishment's transport facilities or alternatively the Authority may be able to assist successful applicants in the purchase of a house. During this period a lodging allowance may be payable. Requests for application forms by Post Card to Senior Recruitment Officer, A.W.R.E., Aldermaston, Berks. Quote Reference 616/WGE/42. W 3172

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY, A.W.R.E., Woolwich Common, requires Technicians Grade I, II, and III, for the following duties:— Technician I (620/WGE/42), to supervise and control several workshops engaged in the manufacture of electronic equipment and to assist a professional engineer in the investigation of new manufacturing processes and the development of prototype electronic equipment. Applicants must be familiar with modern light machine shop practice, including sheet metal work as applicable to radio and the assembly, wiring and testing of electronic equipment. Technician I (624/WGE/42). To control a department engaged in the inspection of mechanical details and assemblies and in the inspection and testing of electronic equipment. Duties will also involve the design of electronic test equipment for use on a production line. Applicants should be familiar with the testing and inspection of electronic equipment and have a good knowledge of light engineering workshop practice. Technician II (621/WGE/42) To supervise and control a small group engaged on engineering of prototype electronic equipment for small scale production. Applicants should be familiar with modern electronic components and be conversant with basic electronic design. They should have had some experience of electronic equipment manufacture and of drawing office practice. Technician II (622/WGE/42). To control a team engaged on the planning for production of electronic equipment and to liaise with subcontractors on technical difficulties experienced during manufacture. Applicants should have had previous experience in similar duties. They should be familiar with modern electronic components and manufacturing processes. A knowledge of inspection and contracts procedure would be an advantage. Technician II (625/WGE/42). To control skilled staff engaged in the final testing of electronic equipment. To design test equipment for use on final inspection and production lines and to contribute to the production of prototype electronic equipment. Applicants should have had previous experience of similar duties. They should also be familiar with modern electronic components and manufacturing techniques. Technician III (623/WGE/42). To assist in engineering of prototype electronic equipment and to carry out planning of small scale production. Applicants should be fully conversant with modern electronic components and be familiar with basic electronic design. They should have had some experience of electronic equipment manufacture and of drawing office practice. Technician III (626/WGE/42). To control skilled staff engaged in the making of a wide range of models, formers, moulds, etc., in wood. To advise on the purchase of timber and to design instrument cases and special packing cases for shipment of apparatus. To control a paint and spray shop. Applicants should have had previous experience of the type of duties detailed. Applicants for all posts should have served a recognized engineering apprenticeship and possession of H.N.C. or O.N.C. or equivalent qualifications is desirable. Salary: Technician I £830-£1,015 (male). Technician II £710 (linked to age 30) to £830 p.a. (male). Technician III £575 (linked to age 26) to £715 p.a. (male). In addition a London allowance will be payable. The successful applicants will be required to join the Authority's superannuation scheme. Requests for application forms by postcard to Senior Recruitment Officer, A.W.R.E., Aldermaston, Berks, quoting the appropriate reference number. W 3180

THE UNIVERSITY OF MANCHESTER. Applications are invited from graduates for a Lectureship in the Fluid Motion Laboratory. The person appointed will be required to work on problems of electronics and instrumentation for the measurement and observation of fluid flow, including turbulence, the propagation of shock waves and aerodynamic noise. Salary on a scale £650-£1,350 per nnum; initial salary according to qualifications and experience. Membership of F.S.S.U. and children's allowance scheme. Applications should be sent not later than 5th June, 1955, to the Registrar, The University, Manchester, 13, from whom further particulars and forms of application may be obtained. W 3160

UNIVERSITY COLLEGE OF THE GOLD COAST. Applications are invited for the post of Chief Technician in the Department of Physics. Duties include supervision and training of laboratory staff, responsibility for apparatus and stores, preparation of lecture and laboratory material for teaching up to B.Sc. (Special) Degree level. Candidates should have either considerable experience of similar work in a University institution or an Honours or Special Degree in Physics. Opportunity for post graduate research may be provided if a graduate is selected. Three-year contract in first instance. Salary £1,100 per annum with a gratuity of £150 in lieu of superannuation provision. Family allowance £100 per child (maximum £500 per annum). Part furnished accommodation at a rent not exceeding 7·5 per cent of salary. Outfit allowance on first appointment. Annual leave eight weeks in United Kingdom. Passages provided for appointee, wife, and maximum of five children. Applications (6 copies) with the names of three references should be sent, before 20th June, 1955, to the Assistant Registrar (London), 29 Tavistock Square, London, W.C.1, from whom further particulars may be obtained. W 3212

UNIVERSITY OF BRISTOL. The University invites applications for appointment to the academic staff of the Electrical Engineering Department. Special interests in industrial electronics (not radio communications), or in electrical control and measurement, are desired. The department has recently moved into entirely new and re-equipped premises, and is expanding its activities, both in teaching and in research. Salary range £550 to £1,350 with family allowance: initial salary according to age and qualifications. Further particulars may be obtained on request: H. C. Butterfield. Registrar, The University, Bristol, 8. W 3243

UNIVERSITY OF CAMBRIDGE. A Technical Officer is required in the Department of Physical Chemistry to hold office from 1st October 1955. This appointment will be subject to the Statutes and Ordinance of the University. The Stipend is in the range £750×£25—£1,050 a year with F.S.S.U., the starting rate depending on experience. The qualifications required are an Honours Degree in Electrical Engineering, Physics or Chemistry, with experience in the design and construction of electronic apparatus for the study of chemical problems, with special reference to flash discharges and microwave spectroscopy. There will also be facilities for a limited amount of independent research. Further details may be obtained from Dr. F. B. Kipping, University Chemical Laboratory, Pembroke Street, Cambridge. Applications close 1st July 1955. W 3213

UNIVERSITY OF CAMBRIDGE. Faculty of Engineering—Notice. Applicants are invited for the post of Assistant in Research in the Department of Engineering. The successful candidate will be expected to work full-time in research into fundamental problems in Control Engineering (Automatic controls and Servo-mechanisms). Applicants should have a University Degree in Engineering. Physics or Mathematics, and some research experience, probably in industry, is desirable but not essential. Salary £500 p.a. rising by £25 p.a. to £700 p.a. and a family allowance of £50 is payable for each child. Some years seniority may be given to the successful applicant if he has had research experience. Forms of application and other particulars may be obtained from the Secretary of the Faculty Board of Engineering, Engineering Laboratory, Trumpington Street, Cambridge. Applications to reach him by 20th June, 1955. W 3244

UNIVERSITY OF NOTTINGHAM. Senior Research Studentship. One Senior Studentship, value £500 per annum for a maximum of three years, is offered as from 1st October 1955 for research in Civil, Electrical, Mechanical or Mining Engineering, or in Metallurgy. Candidates must be graduates who have had not less than two years' suitable experience in industry subsequent to graduation, or who are corporate members of a professional institution. Further information relating to the above may be obtained from the Registrar, to whom forms of application must be returned by 1st July 1955. W 3154

CLASSIFIED ANNOUNCEMENTS
continued on page 4

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EVERY CLAIM we have made for these remarkable units has been substantiated by users and experts (including F. J. Camm, John Gilbert, P. Wilson, H. J. Barton-Chapple and L. Ormond Sparkes) — they have produced the largest volume of unsolicited testimony ever known in the history of loudspeaker manufacture.

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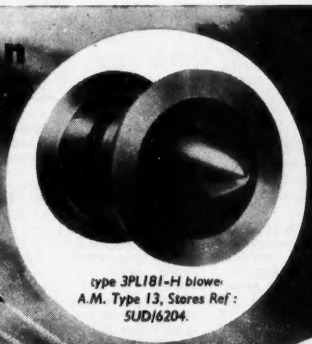

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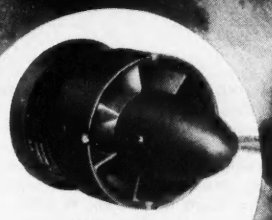

type 2PL81-H blower A.M. Type 12A, Stores Ref 5UD/6205

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OFFICIAL APPOINTMENTS (Cont'd.)

VACANCIES IN GOVERNMENT SERVICE at Cheltenham. 1. Instrument Makers with fitting and machine shop experience in light engineering. 2. Teleprinter, Radio and Electronic Mechanics and Assembler Testers with experience of telecommunications equipment. Basic Pay—£7 18s. 10d. plus merit pay up to £2. 10s. assessed at interview, based on ability and experience. Opportunities for permanent and pensionable posts. Apply in writing only, giving personal particulars to Personnel Officer, G.C.H.W. (Foreign Office), 53 Clarence Street, Cheltenham. W 3029

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 *inclusive or a woman aged* 18-59 *inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order,* 1952.

AERODYNAMICISTS. Physicists, Mathematicians and Engineers. A rapidly expanding aircraft instrument firm engaged on the design and development of autopilots for aircraft and helicopters has vacancies for the following: (a) Stability and control analysis. (b) Flight simulator assessment of aircraft stability. (c) Aircraft Flight Trials of Equipment. Previous experience in the aerodynamics or flight test department of aircraft or guided weapons industry desirable but not essential. Please apply giving full details of career and salary required (which will be treated in strict confidence) to: Personnel Officer, Louis Newmark Ltd., Prefect Works, Purley Way, Croydon, Surrey. W 3249

A. H. HUNT (CAPACITORS) LIMITED require engineers for design and development of paper, mica and ceramic capacitors. Applicants should have previous training in electrical engineering at least to intermediate B.Sc. standard. Apply Personnel Manager, A. H. Hunt (Capacitors) Limited, Bendon Valley, Garratt Lane, Wandsworth, S.W.18. W 212

AIRCRAFT RADIO AERIALS. Gloster Aircraft Co. Ltd., Gloucester, have a vacancy for an Electronic Engineer (H.N.C. or equivalent) to work on the development of suppressed aerials for aircraft. The work involves theoretical and practical knowledge of measurements from "H.F." to "X" bands and of the properties of different types of suppressed aerials. A small laboratory is being established for the work. An elementary knowledge of aircraft design and construction would be an advantage. Applications stating age, previous employers and experience, etc. should be addressed to the Employment Officer. W 1319

AN ASSISTANT DEVELOPMENT ENGINEER is required who is accustomed to telephone practice, including simple automatic systems. He should have some knowledge of audio frequency electronics and of acoustics. The salary would be in the range £500-£650 p.a. Apply to Chief Engineer, Winston Electronics Ltd., 1 Park Road, Hampton Hill, Middlesex. W 1337

A LEADING RADIO and Television Manufacturing Company requires the services of a Chief Engineer. Salary up to £3,000 per annum, according to qualifications and experience. Superannuation and Insurance Schemes in operation. Please reply, in strictest confidence, giving full details to Box No. W 3030.

APPLICATIONS are invited from Engineers and Technicians with experience or aptitude in the following fields of Industrial Instrumentation: Engineering Research leading to construction of prototype instruments employing latest electrical, electronic, pneumatic and hydraulic techniques in measurement, control, information storage and system analysis. Laboratory evaluation of prototype and production instruments. Full details, in confidence, to Technical Director, Short & Mason Limited, Hale End Road, London, E.17. W 1346

AN ELECTRONIC or electrical engineer of degree standard is required to take charge of the Engineering Department in a factory which is part of a large organization engaged in the manufacture of all branches of communications equipment. The successful applicant will be responsible for engineering development, design, and specification of all new items, as well as routine engineering problems. The wide field of work to be covered offers considerable opportunity for advancement. Living accommodation for single or married persons can be made available. Box W. R2419, A.K. Advertising, 212a Shaftesbury Avenue, London, W.C.2. W 3067

APPLICATIONS ARE INVITED from Senior Project Engineers with a specialized knowledge of the manufacture of Electrical and Mechanical products. Applicants should have a good practical engineering background and a sound technical experience of Tool Design and Planning and be capable of putting new projects on a sound production basis. These vacancies offer excellent opportunities to men seeking permanent and progressive positions. London Area. Applications which will be treated in confidence, should give full details of experience and salary required and be addressed to Box No. W 3103.

A PROGRESSIVE COMPANY engaged in the manufacture of plastic laminates and mouldings is forming an electronics division, for which the following staff is required: (i) Senior Electronic Engineers or Physicists with at least four years' experience of the design of pulse or microwave radar circuits. (ii) Engineers or Physicists who have recently graduated and who possess a sound knowledge of electronic circuit theory. (iii) Radio-mechanics with several years' experience. Good opportunities and high salary rates. Write full details of past experience to Managing Director, Microcell Ltd., 56 Kingsway, W.C.2. W 3157

AUTOMATIC TELEPHONES & ELECTRIC COMPANY LTD., Liverpool, 7. Communication Engineers and Draughtsmen. The transmission Department invite applications in senior, and junior, categories for Line Transmission Laboratory Engineers, and Apparatus Design Engineers, and also Draughtsmen with experience in telecommunication and light current engineering. Expanding programmes offer progressive opportunities in interesting work. Specialist experience in any branch of line transmission engineering is desirable for some of the posts. The positions offered are on the Company Staff, with contributory Pensions Fund, and usual staff conditions. Assistance in establishment in the Liverpool area will be given in approved cases. Applicants should write to the Personnel Manager, Automatic Telephone & Electric Co. Ltd., Strowger Works, Edge Lane, Liverpool, 7, giving full details of age, experience and qualifications. W 222

AUTOMATIC TELEPHONE & Electric Company Ltd., Liverpool. Senior Lecturer School of Electronics. Applications are invited for the post of full time Senior Lecturer in the School of Electronics. Candidates must hold a Degree in electrical engineering which includes the subjects, Electronics and Telecommunications. Applicants should have had both teaching and industrial experience, and a knowledge of electronic switching techniques would be an advantage. Salary as for Senior Lecturer, Burnham Technical Scale. Commencing salary according to experience and qualifications. Further details and application forms may be obtained from the Personnel Manager, Automatic Telephone and Electric Co. Ltd., Strowger Works, Edge Lane, Liverpool, 7. W 3193

A VACANCY exists for an Electronic Instrument Development Engineer in the Telecommunications Laboratory of British Insulated Callender's Cables Ltd., at Kirkby, near Liverpool. Candidates should hold a degree in Physics or Engineering and have previous experience in the design and development of Electronic Instruments. Applications quoting reference P/60/54 should be addressed to: The Staff Officer, B.I.C.C. Ltd., Prescot, Lancs. W 3223

BURNDEPT LIMITED have vacancies, due to expansion for: (1) Telecommunications Development and Research Engineers. Qualified to operate as Project Leaders under direction of Chief Engineer on Government and proprietary designs. Experience must be within one or more of the following fields:— (a) Aeronautical Telecommunications, both Airborne and Ground Station designs, with special emphasis on U.H.F. techniques with the field. (b) F.M. single and multi-channel equipment development in both V.H.F. and U.H.F. bands. (c) Development of subminiaturization techniques and special components. (2) Telecommunications Laboratory Instrument Mechanics and Wiremen. Must be fully conversant with modern miniature and subminiaturization techniques, and be able to wire from circuit diagrams on own initiative. Those capable of converting experimentally wired models to final stage by own initiative will receive special consideration. Excellent working and model shop facilities. Applications, giving full particulars, including present salary, should be sent in confidence to Personnel Manager, Burndept Limited, Erith, Kent. W 3220

CHIEF ENGINEER. A manufacturer of a wide range of aircraft equipment situated in the Midlands intends to appoint a Chief Engineer to control the work of a large engineering department. Applicants should be about 40, highly qualified, and capable of effective direction of several design teams. The post is permanent, pensionable, and a salary of about £2,500 is offered to a resolute and capable executive who meets these requirements. Applications in confidence quoting reference CE.01 to Box No. W 3222.

CHIEF MECHANICAL DESIGNER for Research Department of large manufacturers of electronic equipment. Previous experience in electronic industry essential. Salary up to £1,500 p.a. North London area. Write Box W 3162.

DECCA RADAR Limited have, due to the continued expansion of their Research Laboratories, a number of vacancies for Circuit Design Engineers. These cover work in a wide field embracing high and low power pulse. receiver, A.F.C., radar display, and test equipment design in standard and sub-miniature form. Applicants should be of Degree standard; experience is desirable but not essential. There is a pension scheme in operation. British Nationality. Please write, quoting RLA 93 to Decca Radar Limited, Research Laboratories, 2 Tolworth Rise, Surbiton, Surrey. W 219

DECCA RADAR LIMITED invite applications from electrical engineers and physicists of degree standard, having practical experience in microwave components, to work on advanced microwave and millimetric aerial design in a rapidly expanding Group: the prospects for men of ability are considerable. British Nationality Essential. A Pension Scheme is in operation. Please write to Decca Radar Limited, 2 Tolworth Rise, Surbiton, Surrey, quoting reference RLA 95. W 221

DECCA RADAR LTD. Opportunities exist for young men to be trained in precision measurements on microwave and electronic equipment. Applicants should have basic knowledge of radio principles and preference will be given to those anxious to continue their studies. Senior posts are available to engineers with experience in the microwave or electronic fields. Applications should be made in writing giving details of experience and stating salary required to The Chief Inspector, Decca Navigator Co. Ltd., Malden Way Factory, New Malden, Surrey. W 3219

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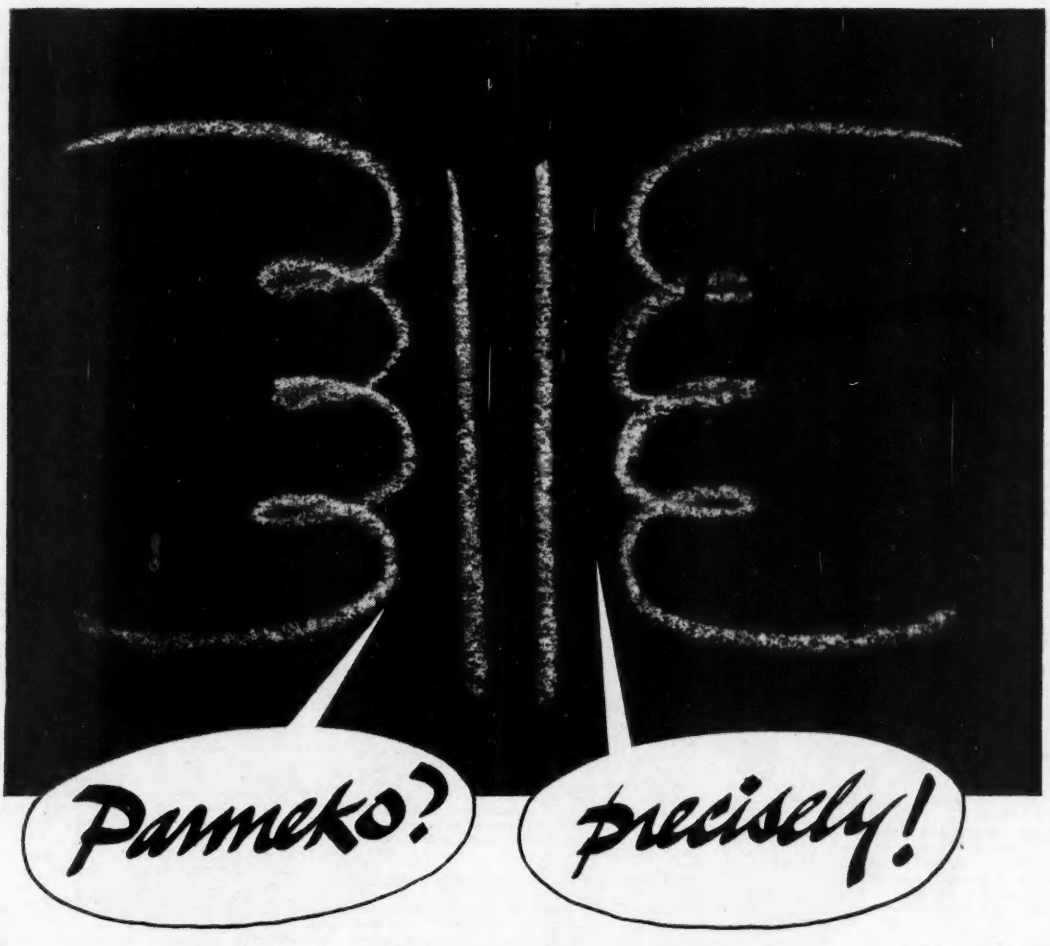

What's this thing between us, George, that prevents our seeing eye to eye ?

It's that darned line of Parmeko's. . . .

You mean that ' one-track mind ' of theirs ?

That's exactly what I do mean, old boy.

Aren't they a little off the rails, George ?

Not on your transformers ! Single purpose, single plant—one man, one job team of technicians—planning, perfecting, dreaming only transformers. . . .

But where does all this singlemindedness lead to, George ?

To the finest transformers possible—and other things ; as we shall see if, as they say in advertisements, we watch this space.

PARMEKO *of* **LEICESTER**

MAKERS OF TRANSFORMERS FOR THE ELECTRONIC AND ELECTRICAL INDUSTRY

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

DECCA RADAR LTD An electronic engineer is needed for a key position in a Radar System team. Candidates should be of a Higher National or Degree standard. A pension scheme is in operation. Applicants should be of British Nationality. Reply quoting reference RLA 81 to Decca Radar Limited, 2 Tolworth Rise, Surbiton, Surrey. W 220

DECCA RADAR LIMITED plan in the near future to put a new project on to the market and seek a first-class production engineering designer (preferably with both electronic and mechanical experience) to take charge of the project. Substantial salary on a rising scale. British Nationality essential. There is a Pension Scheme in operation. Reply quoting reference RLA 90 to Decca Radar Limited, Radar Research Laboratory, 2 Tolworth Rise, Surbiton, Surrey. W 216

DECCA RADAR LIMITED invite applications from young men, preferably of H.N.C. standard or above, who would like to become microwave engineers working in the modern wide field of navigational aids. Training will be given to suitable applicants to fit them for a progressive career. British Nationality essential. There is a Pension Scheme in operation Write giving full personal particulars and quoting RLA 91 to Decca Radar Limited, Radar Research Laboratory, 2 Tolworth Rise, Surbiton, Surrey. W 217

DECCA RADAR LIMITED require the services of a first-class mechanical engineer for work on their Microwave Link Systems. This post is a special appointment and a substantial starting salary is envisaged on a rising scale. British Nationality essential. Pension Scheme in operation. Please write giving full particulars and quoting RLA 89 to the Research Director, Decca Radar Ltd., Radar Research Laboratory, 2 Tolworth Rise, Surbiton, Surrey. W 218

DENIS FERRANTI Meters Limited, Bangor, North Wales. Electronics Engineer (Graduate) required by rapidly expanding company situated in a pleasant coastal district. The applicant should preferably have had some design experience. Housing assistance will be given in suitable cases. Apply in confidence to: Chief Electronics Engineer, Denis Ferranti Meters Limited, Bangor, North Wales. W 3251

DESIGN DRAUGHTSMAN, preferably with H.N.C., and with experience of electronic and/or precision electro-mechanical equipment required by the Electrical Research Department. Good starting salary and prospects, with pension scheme and five-day week. Write giving full details of age, experience and qualifications to Personnel Manager, C. A. Parsons & Co. Ltd., Heaton Works, Newcastle upon Tyne, 6. W 3156

DESIGN ENGINEERS & DRAUGHTSMEN are required by Kelvin & Hughes Limited, at their Barkingside, Essex, works for electro-mechanical instrument development work. Recent design experience in a similar, or associated field is required, together with a technical background, preferably of at least Higher National Certificate standard. Applicants should also have had a mechanical engineering apprenticeship, or equivalent practical training, and possession of some knowledge of Electronics is an advantage. The positions are permanent and offer scope within an expanding Organization to designers of progressive outlook who are able to use their own initiative. Written application, in strictest confidence, should be addressed to the Personnel Manager, Kelvin & Hughes, Ltd., New North Road, Barkingside, Essex. W 3086

DESIGNER DRAUGHTSMEN with sound experience of Presision Mechanical or Electro-Mechanical Equipment and holding the H.N.C. required on important work in the London area by Large Engineering Company. Salary in £600/£800 year range to successful applicants, together with a living allowance if coming from outside the district. Positions are permanent and Pensionable. Please write giving full particulars of experience and qualifications to Box No. W 1291.

DESIGNER (25/55 years) required by old-established firm of e'ectrical component manufacturers in N.W. London. Applicants must possess sound knowledge of radio frequency circuits, pulse forming networks and experience in the electronic, radio and/or television industry would be an advantage. Superannuation scheme. Write stating age, experience and salary required to Personnel Manager, Box 3M S4588, A. K. Advg., 212a Shaftesbury Avenue, W.C.2. W 3181

DEVELOPMENT ENGINEERS. A leading Manufacturer of Radio and Television Receivers has vacancies in its Laboratories for Electronic Engineers with experiece in the Design and Development of this type of equipment. Situated in the Midlands. Salaries according to qualifications and experience. Those interested should write, giving details of career and salary expected to the Personnel Manager (Ref. GLB), Box No. W 3037.

DEVELOPMENT ENGINEERS. A medium-company, progressive and expanding, and now establishing new works and laboratory near Sunbury-on-Thames, Middlesex, invite applications from electronic engineers of H.N.C. or Degree standard with practical experience of development. Work is varied and conditions afford interest and scope for initiative with a progressive salary and pension scheme. Interview expenses paid. Applicants please state brief details of training, age, and project experience. Box No. W 3248.

DEVELOPMENT ENGINEERS. Applications are invited from men interested in design work on weighing and recording equipment, embodying electronic and electro-mechanical features, recently marketed by the Company. These are Staff appointments. Salaries commensurate with qualifications and experience. Sick Pay and Pension Schemes are in operation. Write, giving personal particulars, to the Personnel Officer, The British Tabulating Machine Co. Ltd., Letchworth, Herts. W 3054

DRAUGHTSMEN : Vacancies for senior draughtsmen with experience of Electronic and/or Electro-mechanical engineering required, preferably with experience of Ministry requirements. Excellent prospects with good commencing salaries; non-contributory Pension Scheme in operation. Applications will be treated in strict confidence and should give full chronological details of qualifications, experience and age to: John A. Smith Ltd., 24 Lichfield Street, Wolverhampton. W 201

DRAUGHTSMEN. An expanding production programme has created a number of vacancies for Mechanical Designers, Senior Draughtsmen and Detail Draughtsmen. Situated in the Midlands. The work involves the complete engineering of electronic apparatus for Government Contracts and of domestic Radio and Television equipment. Applicants interested in this type of work, with or without experience, are invited to apply, giving details of career and salary expected to the Personnel Manager. (Ref.GLB) Box No. W 2996.

EDITORIAL ASSISTANT for Electrical Engineering Journal. (London). Engineering or Science degree and some engineering experience necessary. Journalistic knowledge desirable but those with literary ability would be considered. Good prospects for advancement. Age approximately 25-30. Salary according to qualifications and experience. Box No. W 3166.

ELECTRICAL AND MECHANICAL ENGINEERS. Sunvic Controls Ltd. (a subsidiary of Metropolitan-Vickers Electrical Co. Ltd.) have the following vacancies in their new Development and Production Units at Harlow. 1 Graduate Engineer with experience in design or development of electro-mechanical mechanisms and their application to instrument problems. 2. Graduate engineer with practical experience in the development of electronic equipment and preferably a knowledge of the latest development in pulse techniques. 3. Application engineer of degree standard with experience in the application of electronic techniques to industrial and process control problems. The above positions are permanent and offer excellent prospects for promotion in a team engaged on the development and manufacture of a wide range of new instruments. Salaries will be according to age and ability. The Company's contributory pension scheme applies in all cases, and housing is available if required. Reply in writing, giving full particulars of age, experience, qualifications and present situation, to Chief Engineer, Sunvic Controls Ltd., Harlow, Essex. W 209

ELECTRICAL DEVELOPMENT ENGINEER required for work on A.A. defence projects at the British associate company of the Hispano-Suiza group. Candidates must have Grad. I.E.E. or equivalent qualification. A sound knowledge of the fundamenta's of electronics and applied mathematics and the ability to learn are of more importance than detailed experience of similar work. The successful applicant will work from the design office but will also be engaged in trials of prototype equipment in the factory and in the field. The post is a permanency and entitles holder to participation in superannuation scheme. Applications with details of age, experience, qualifications and salary required, by post only to British Manufacture and Research Co. Ltd., Grantham, Lincs, quoting ref.: AWK/STAFF/EE. W 1340

ELECTRONIC / ELECTRICAL Engineer required by London Manufacturers of Radio Components to take charge of measurements laboratory and test gear design. Experience of measurement capacitors or telecommunication cables essential. Salary range £750 to £850 p.a. Company rapidly expanding. Write details of qualifications, experience, age and present salary. Box W 3201.

ELECTRICAL / ELECTRONIC / RADIO ENGINEERS. A number of vacancies exist in the Design Organization of Vickers-Armstrongs Limited, Hursley Park, near Winchester. The work will include development, design and testing of latest specialized installations in Aircraft. Applicants with varying qualifications up to Degree standard are invited to apply. Salary commensurate with experience and ability. Recommendation may be made for housing after qualifying period. Apply:— Personnel Department, Vickers-Armstrongs Limited, Hursley Park, near Winchester. W 3129

ELECTRICAL ENGINEER or Physicist with an interest in electronics required for work in the Midlands on a number of interesting development projects concerned with the application of electrical and electronic techniques to industrial processes. Honours Degree is desirable but not essential, particularly if candidates have already had several years' experience in work of a similar nature. Box No. W 3217.

ELECTRICAL ENGINEERS. Vacancies exist in the Electro-Mechanical Section of the development division of a rapidly expanding organization. Work in this section deals with light and servo mechanisms and power supply and control. Qualifications: Engineers holding a degree or equivalent for senior Engineers; National Certificate for junior Engineers. Salary will be according to qualifications and experience. All replies should be addressed to: The Radar Development Division, Decca Radar Ltd., 9 Davis Road, Tolworth, Surbiton, Surrey. W 3161

ELECTRONIC DIGITAL COMPUTERS, men about to leave the armed forces with experience of Radar maintenance are invited to apply for posts now vacant, due to expansion, on this new and interesting type of engineering. Previous experience on this equipment is not essential since training on full salary will be provided at Marconi College to those people who lack the necessary "know how" but possess the interest and enthusiasm for this type of work. Please apply in writing to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. No. 1353D. W 3131

ELECTRONIC PRODUCTION ENGINEER. Small but rapidly expanding subsidiary of a world renowned manufacturing company, requires an experienced Electronic Engineer as Production Manager at their new Richmond unit. Practical experience of production methods more important than academic qualifications. Interesting pioneering work. Excellent scope for keen organizer. Good salary. Write stating fully previous qualifications and experience to Box No. W 3238.

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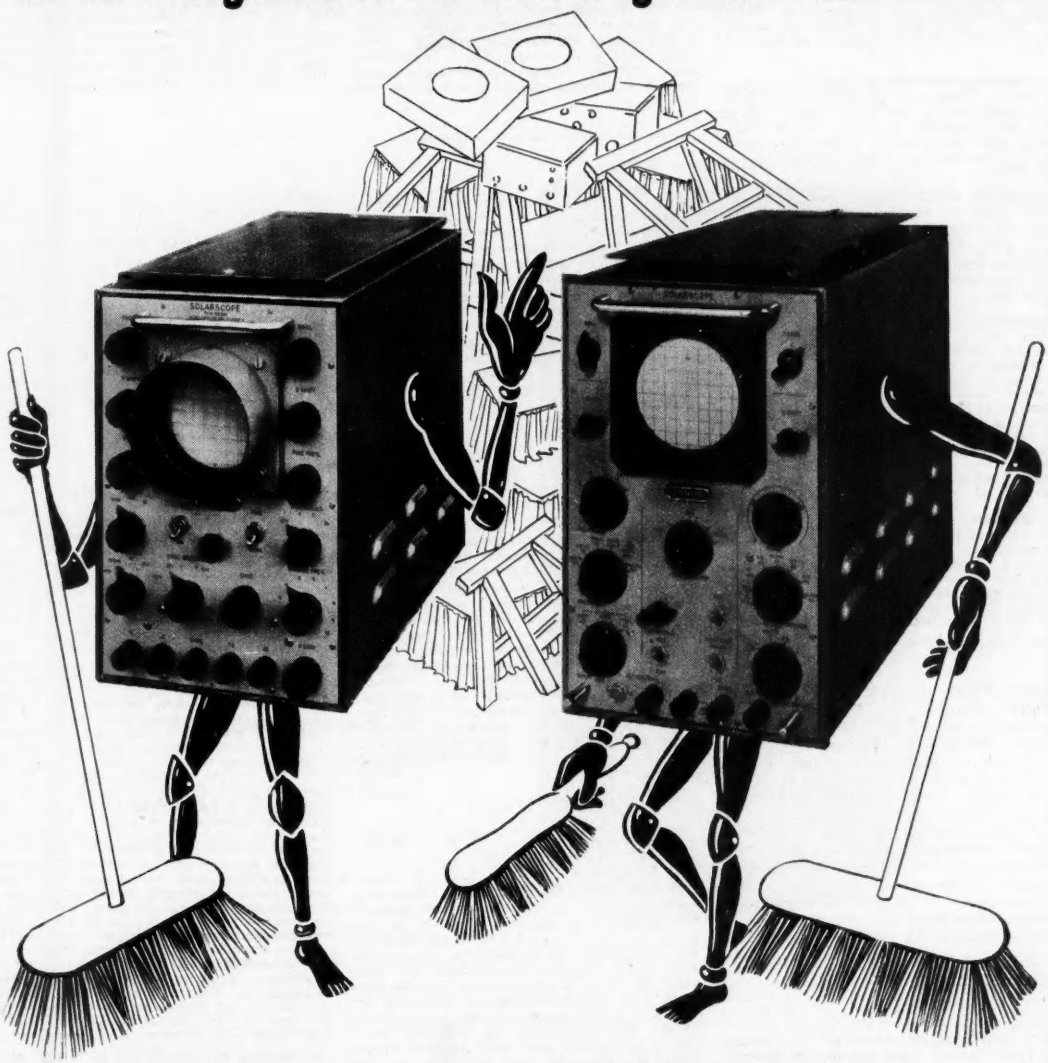
THE 'SCOPES THAT SWEPT

Dr. Frittertime from The Physical Society Exhibition!



BRIEF SPECIFICATION OF CD.514

"Y" Sensitivity : 30 mV/cm—30 V/cm from 5 c/s to 9 Mc/s (3 db)
"Y" Calibration : 50 cycle sine-wave, 100 mV, 1 V, 10 V and 100 V
"X" Expansion : 0.5 to 5 diameters.
Time Calibration : 0.1, 1 and 10 microsec. intervals
T.B. Frequency : 15 c/s to 300 Kc/s
T.B. Trigger Sensitivity : 1 v. R.M.S., minimum
Weight : 40 lbs. Size : 12½" x 8¾" x 16½" deep overall.

BRIEF SPECIFICATION OF CD.513

"Y" Sensitivity : 1 mV/cm maximum
Direct time and voltage measurement
High definition and excellent brilliance
Bandwidth : D.C.—10 Mc/s (3 db)
4 million to 1 time-base range
Identical "X" and "Y" amplifiers
Weight : 70 lbs. Size : 16" x 10" x 23" deep overall.

THE SOLARTRON ELECTRONIC GROUP LTD.

THAMES DITTON, SURREY. TELEPHONE: EMBerbrook 5611. CABLES: SOLARTRON, THAMES DITTON

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

ELECTRONIC ENGINEER—Degree or equivalent, previous design experience of V.H.F. F.M. Mobile equipment essential. Small but rapidly expanding organization on South Coast (near Southhampton). Write full details, age, experience and salary expected to Box No. W 1338.

ELECTRONIC ENGINEER required to design and develop Electronic Instruments and Test Gear. Experience in this field essential. Good salary and excellent prospects for advancement in expanding company. Rivlin Instruments Ltd., 7a Maitland Park Villas, London, N.W.3. GUL 2960. W 1345

ELECTRONIC ENGINEER required by London manufacturers of Radio Components to take charge of measurements Laboratory and test gear design. Experience of measurement of capacitors or telecommunication cables essential. Salary £750 p.a. Write details of qualifications, experience, age and present salary. Box No. W 186.

ELECTRONIC ENGINEER, to control Laboratory and be responsible for Works Standards and general Test Equipment, etc. Must be capable of carrying through to conclusion investigations/development of radio variable condensers and equipment for frequencies including V.H.F. Applicants must have good educational background, considerable industrial experience, and be used to controlling staff. Write concisely, stating qualifications, experience, age and salary required to Wingrove & Rogers Limited, Domville Road, Old Swan, Liverpool, 13. W 223

ELECTRONIC ENGINEERS are wanted in large Midland Engineering Plant, the positions are progressive and interesting requiring qualified and experienced Electronic Engineers, Senior and junior for rapidly expanding laboratory engaged upon measurement and control problems. State age, qualifications and experience fully, in confidence, to Box No. W 3109.

ELLIOTT BROS. (LONDON) Ltd., Electronic Engineers, Physicists, Mechanical Designers. Applications are invited from Electronic Engineers. Physicists and Mechanical Designers who would be interested in joining a new research and development team to operate in the Company's establishment at Weymouth. Vacancies exist at all levels including that of Chief Engineer and an interesting field of work involving advanced Electronic and Mechanical techniques is planned. Applications, which will be treated in the strictest confidence, stating age, experience and qualifications to Personnel Manager, Elliott Bros. (London) Ltd., Century Works, Lewisham, S.E.13. W 3149

E.M.I. Engineering Development Ltd., Assistant Trials Planner. An assistant is required for trials planning at the Company's Feltham laboratories. The engineer we are looking for will have H.N.C. or similar qualifications, and 3-6 years' experience, preferably in trials activity, and should be willing to travel. A knowledge of telemetry will be a distinct advantage. The salary for this pensionable post is attractive and prospects in this active and steadily expanding company are excellent. Please reply in the first instance to Personnel Dept. (ED/246), E.M.I. Engineering Development Ltd., Blyth Road, Hayes, Middlesex. W 3198

E.M.I. Engineering Development Ltd. The following vacancies exist for staff in a team developing Electronic Business Machines. (1) Electronic Circuit Engineers with experience of low power pulse circuits magnetic recording or digital computers. (2) Electro-Mechanical Engineers with experience of design or development of keynotes for office machines, electric typewriters, teleprinter equipment or similar electro magnetic devices. (3) Assistant Programmers preferably with experience of office systems, or programming for digital computers. The positions are pensionable and offer good starting salaries with excellent prospects. Applicants should write with full details to Personnel Dept. (ED/248), E.M.I. Engineering Development Ltd., Hayes, Middlesex. W 3214

E.M.I. Engineering Development Ltd. Experienced Valve Engineer, An interesting vacancy has arisen at the Company's Feltham laboratories for a Valve Engineer with 4-6 years' experience of both valve and micro-wave generators. Applicants who should be qualified, will have some knowledge of testing both in quantity and for special purposes, will be able to design suitable test equipment, and have some applications experience. The salary offered for this pensionable post is attractive, and the prospects in this active company, are excellent. Please address your first reply to, Personnel Dept. (ED/244), E.M.I. Eng. Dev. Ltd., Blyth Road, Hayes, Middlesex. W 3215

E.M.I. Engineering Development Ltd. Circuit Design. An attractive vacancy has arisen at the Hayes Laboratory of this active and expanding company. We want a first-grade electronics man to design and develop original circuits ranging from pulse circuits for radar display to those related to computers and servomechanisms. The successful candidate will be qualified, and will have had some experience in this or an analogous field. The post is pensionable, the salary commensurate with experience and ability, and the prospects are excellent. Please reply in the first instance to, Personnel Dept. (ED/236), E.M.I. Engineering Development Ltd., Blyth Road, Hayes, Middlesex. W 3192

E.M.I. Engineering Development Ltd. Redevelopment Authority. A vacancy has arisen for a Senior Electronics Engineer who will be prepared to take over, on behalf of the company, full responsiblity for a Radar or Communications system used by the Services. His main tasks will be to formulate plans for redevelopment with special reference to increasing the reliability and extending the use of the equipment The post carries an attractive salary and is pensionable and holds out great opportunity for the right man. Reply in the first instance to Personnel Dept. (ED/240), E.M.I. Eng. Dev. Ltd., Blyth Road, Hayes, Middlesex. W 3196

ENGINEER with electrical or physicist degree required for development work on testing equipment for telecommunication cables. Permanent and pensionable position at salary commensurate with experience and qualifications. Please apply, giving full particulars to Personnel Officer, Southern United Telephone Cables Ltd., Dagenham Dock, Essex. W 1316

E.M.I. Engineering Development Ltd. Aircraft Electronic Equipment. An extremely interesting vacancy has arisen within the company, for an Engineer to take responsibility for the solution of problems associated with the installation of all types of electronic equipment in aircraft. The successful applicant must have had wide experience in this field. He must appreciate both the aeronautic and the electronic engineer's viewpoint. The post is pensionable, the salary will be commensurate with ability and experience, and the prospects are excellent. Please reply in the first instance to, Personnel Dept. (ED/241), E.M.I. Engineering Dev. Ltd., Blyth Road, Hayes, Middlesex. W 3197

E.M.I. Engineering Development Ltd. Micro-Wave Design Work. An engineer is required at the Company's Feltham laboratories to collaborate on micro-wave component design and to investigate problems arising from quantity manufacture of micro-wave components and aerials. Applicants should have 4-6 years' experience and a Degree in science or engineering would be a distinct advantage. An attractive salary is proposed for this pensionable post, and prospects in the company, which is steadily expanding, are considerable. Please reply in the first instance to Personnel Dept. (ED/245), E.M.I. Eng. Dev. Ltd., Blyth Road, Hayes, Middlesex. W 3195

ENGINEERS AND PHYSICISTS. Ferranti Limited in their new Laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computers to control machines and industrial processes and covers a wide and expanding field of application, offering long-term interest to those engaged in it. Development activity for these projects is taking place in the field of electronic circuitry (including pulse technique), digital computers, magnetic recording and servomechanisms. Engineers and Physicists having experience as well as interest in one or more of these subjects are invited to apply. The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff Pension Scheme. Application Form will be sent on request (quoting Ref.: EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5. W 3225

ERICSSON TELEPHONES LTD. have in their Research Laboratories a number of vacancies for circuit designers and equipment engineers to work on nucleonic instruments, and interesting new developments in electronic computing and switching; both senior and junior posts are available. Applicants should have a degree or equivalent plus several years' experience of appropriate work for the senior posts; correspondingly reduced qualifications and experience will be accepted for junior posts. Salaries will be in accordance with age, qualifications and experience. Applications, giving details of age, academic or other training and qualifications, experience, and starting salary required, should be sent to the Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 197

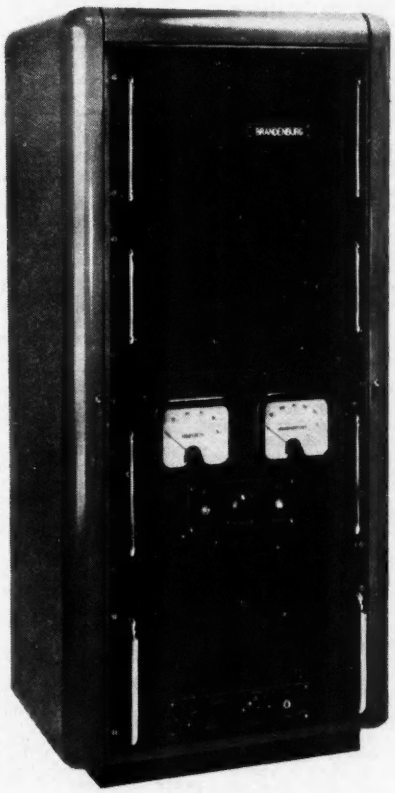
EX NAVAL R.E.A.s, R.E.s, or R.A.F. air or ground radar fitters. Applications are invited for employment on Development and Prototype Testing of Radar and Guided Weapon Equipments. There is plenty of scope for enthusiastic men with initiative and ability. The work is interesting and working conditions are good. The positions offered are permanent and are covered by a contributary pension scheme. Salary according to age and experience. App'ications should be made to the Personnel Manager, The General Electric Co. Ltd., Brown's Lane, Allesley, Coventry, Ref. RG/B. W 3236

CLASSIFIED ANNOUNCEMENTS
continued on page 10

brandenburg *high voltage equipment*

a **special** design
to fulfil a
special function

This Brandenburg generator was designed to supply micro-focus x-ray spectrometers, electron-microscopes, and electron diffraction cameras



specification

output

12 KV.—50 KV. Continuously variable. 5 volts 3 amperes isolated to 50 KV.

stability

Better than 0.1% against mains variation of −10% and + 5% and load variation of zero to 0.5 MA.

metering

Two 5" Ernest Turner Grade 1 moving coil instruments calibrated in kilovolts and microamperes respectively

From the Brandenburg range of standard and specialized radio frequency and low frequency high voltage equipment, including high voltage generators; stabilized power supplies; high voltage measuring instruments, and ionization measuring equipment

Teleonics | communications | Limited

196 Dawes Road, London, S.W.6 Fulham 1534

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

ENGINEERS and Engineering Draughtsmen for new department. The work is concerned with the development and design of high performance closed-loop systems. Electrical Engineers for circuit development work on electronic, magnetic, and transistor amplifiers as used in high performance servo mechanisms and regulators. A good Degree and experience in this field is desirable, but not essential. For the more junior positions a Higher National Certificate in electrical or electronic engineering is satisfactory. Electrical Engineers for control circuit design on closed-loop systems employing electronic and magnetic amplifiers used in conjunction with electric and hydraulic machinery. A good general engineering background is desirable as these positions include design, coordination, and the preparation of specifications. Qualifications required are engineering Degree, and/or corporate membership of the Institute of Electrical Engineers, although electrical engineering Higher National Certificate or equivalent is satisfactory for the more junior posts. Mechanical Engineers for:— (1) Work on design of precision gear boxes in which close control of backlash and high mechanical stiffness is important. (2) Work on design of small electro-mechanical devices including sliprings, controllers, and small precision gear boxes. (3) Work on design of large structures supporting rotating masses and electrical control gear and associated power drives. The important design parameters are the maintenance of high structural stiffness and low weight. Qualifications for mechanical engineers are mechanical engineering Degree, and/or corporate membership of the Institute of Mechanical Engineers, although for more junior posts mechanical Higher National Certificate or equivalent would be acceptable. Engineering Draughtsmen for layout and detail work for duties in connexion with the mechanical design of amplifiers and control cubicles. Previous experience in this field is not essential. Qualifications required are Ordinary National Certificate, Higher National Certificate or equivalent. Mechanical Diagram Draughtsmen for schematic detail and cable diagram work on amplifiers and control systems. Previous experience on diagram work is desirable and technical training should be up to Ordinary National Certificate standard, but preference will be given to candidates holding Higher National Certificates or equivalent. Mechanical Design Draughtsmen. Men with good experience for layout and detail work in connexion with design of mechanical structures, gear boxes, and light electro-mechanical devices. Qualifications: Higher National Certificate in mechanical engineering or equivalent. For junior positions candidates approaching Higher National Certificate standard or equivalent will be considered. All these posts are permanent and pensionable. Write for application form to:— The Personnel Manager, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17. Mark envelope "E.2". W 3191

EXPANSION in the Programme of S.W. London Company Manufacturing Industrial Instruments and Controls requires Physicists, Electrical and Mechanical Engineers for development of new ideas in this field. Applicants to be of graduate status or equivalent professional qualifications. Two positions for seniors up to £1,500 p.a. Several years' experience of industrial or academic research required for these—but several vacancies exist for development Engineers having relevant experience—salaries up to £1,200 p.a. Applicants should state age and past experience, qualifications. To C.D.E. Box No. W 3252.

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers, wirer and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

ENGINEERS REQUIRED for new and expanding Research Laboratory in the Surrey/Hampshire Area. The work consists of fundamental studies in a variety of branches of Electronics. The posts offer scope for initiative, considerable freedom of action and opportunities for advancement. Vacancies exist for the following posts:— (1) 1 Senior Engineer to take charge of a group studying initially problems of Microwaves. (2) 1 Senior Engineer to take charge of a group engaged initially in a Mathematical and Experimental Study of Modulation. Applicants, who should be graduates or equivalent, should have had several years' experience in research or development work, although not necessarily in the field indicated above. Commencing salary, according to qualifications and experience, in the range £800-£1-200. (3) 4 Engineers to work in the above groups. Applicants should preferably possess a degree or H.N.C. and have had some experience in Electronic Development. Commencing salary according to qualifications and experience, in the range of £700-£900. (4) 4 Draughtsmen to work on the above projects. (5) 3 Instrument Makers to work on the above projects. These positions are permanent and facilities are available for Company Insurance and Superannuation. Please reply, in confidence, giving full details of qualifications and experience to Box No. W 3112.

FERRANTI ELECTRONIC COMPUTERS. Interesting posts are immediately available in connexion with the installation and post-installation service of a new series of electronic digital computers. Candidates should possess a Degree or Higher National Certificate in Electrical Engineering, and be willing to travel to any part of the world or to be based anywhere in this country. Suitable allowances are made for expenses. The appointments are to the permanent staff of this new and expanding Ferranti department. The Company operates a Staff Pension Scheme. Application forms from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference DCM. W 3239

FERRANTI LIMITED, Edinburgh. Graduate Engineers are required for the design and manufacture of Radar and Fire Control systems. The work involves all aspects from system study, component and general design and flight trials production. The Instrument and Fire Control Division particularly require Graduate Engineers interested in the design and development of:— Magnetic Amplifiers; Analog Computers; Electronic Circuits; for these systems. Previous experience in this class of work is desirable. There are also vacancies for experienced men with Higher National Certificate, or similar qualifications. Apply, giving full particulars of academic training and experience, quoting Ref. G/I/L, to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh 5. W 3153

FERRANTI LIMITED, Edinburgh have vacancies for additional Junior and Senior Draughtsmen who are suitably qualified and interested in the design of (a) Instruments, (b) Light Precision Mechanisms, (c) Electronic Equipment and (d) Machine Tools. Experience in any of the above headings is an advantage, but not essential for these vacancies. Apply quoting Ref. 23/D.D.O. and give full details of training and experience in chronological order to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5. W 3124

FOREMAN required for Electronic Company. Small batch production of high quality equipment. Excellent prospects in expanding organization for person with ability and drive. Rivlin Instruments Ltd., 7a Maitland Park Villas, London, N.W.3. GUL 2960. W 1341

FERRANTI LIMITED, Edinburgh. Engineers. Applications are invited for positions in our Production organization which is engaged in the manufacture of precision electromechanical/electronic equipment. Applicants should hold a Degree or diploma in Electrical Engineering, Mechanical Engineering or equivalent, but consideration will be given to applicants holding a H.N.C. in Engineering and who have completed an engineering apprenticeship. The vacancies are for:— (A) Engineers to work on the application of computer-controlled machine tools with reference to the utilization of these in a production organization, investigation into the material handling, setting, jigging and fixing methods to be employed with such machines. (B) Project Engineers to take charge of the complete manufacture of complex electromechanical/electronic equipment—experience in production operations is essential in this case. (C) Technical Project Engineers who do not possess the necessary practical experience for (B) but have a flair for production matters and who would act as technical assistants to the Project Engineers in the first instance with a view to promotion to Project Engineers in due course. Salary according to age, qualifications and experience. Staff Pension Scheme. Ideal working conditions in modern factory furnished with the most modern equipment. Please address full details of technical qualifications, age and experience and stating post applied for to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, quoting ref.: 23/FE. W 3182

FOREMAN AND CHARGEHAND required with experience of electronic equipment and/or light electro-mechanical assemblies. Male and female labour. Previous supervisory experience essential. Please reply, giving details. Box No. W 3164.

GRADUATE ELECTRONIC ENGINEERS, are required by Ferranti Limited, Edinburgh, for technical duties related to the production of Radar Equipment. Previous Radar experience is desirable. Consideration will also be given to non-Graduates with equivalent qualifications and experience. Replies should be addressed to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh 5, quoting Ref. E.37/EL. W 3152

GRADUATE MECHANICAL ENGINEER required for design and development of small mechanical devices used in conjunction with electronic equipment. Specialized experience not essential. Apply quoting reference JB, to Southern Instruments Ltd., Camberley, Surrey. W 3150

G9AED EXPERIMENTAL TELEVISION TRANSMITTER. South Norwood. A full-time operator is required, capable of locating and rectifying circuit and component faults, academic qualifications not essential: training period given. Applicants should be mobile and prepared to move to the Midlands for a short period if necessary, after a few months. On closing down the transmitter the operator will be transferred to the Company's permanent technical staff. Applications (in confidence) giving full details of qualifications and experience with some indication of salary required to The Secretary, Belling & Lee Ltd., Great Cambridge Road, Enfield, Middlesex. W 3176

HATFIELD INSTRUMENTS LTD., who are now expanding their laboratories require senior and junior electronic engineers with experience in the design and test of high grade Radio and Industrial Laboratory Equipment. Apply in writing in the first instance stating age, experience and salary required to Hatfield Instruments Ltd., 175 Uxbridge Road, Hanwell, W.7. W 3038

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

HIGH VOLTAGE ENGINEERS and Physicists required by the Nelson Research Laboratories, The English Electric Co. Ltd., Stafford. Preference will be given to applicants with an Honours Degree. Salary according to experience and qualifications. Apply Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref.: 229D. W 3179

HONOURS GRADUATE in physics or electrical engineering is required to work in a laboratory engaged in research and development on frequency control problems relating to communication systems. The position is open to men and women and affords excellent opportunities for detailed study of the theoretical and practical aspects of the subject. Living accommodation for single or married persons can be made available. Box W. R2423, A.K. Advg., 212a Shaftesbury Ave., London, W.C.2. W 3066

HONOURS GRADUATES in Physics or Electrical Engineering are required for advanced work in a Quartz Crystal Laboratory. The positions offered afford excellent opportunities for young men or women to specialize in the study of piezoelectric materials from both the theoretical and practical viewpoints. An interest in mathematics and electronics would be an advantage for this work. Living accommodation can be made available to successful applicants. Write Box W. Q9365, A. K. Advg., 212a Shaftesbury Avenue, London, W.C.2. W 3041

IMPERIAL CHEMICAL INDUSTRIES Ltd., Wilton Works. Draughtsmen. Imperial Chemical Industries Limited, Wilton Works, is engaged on further extensive developments and requires to extend its drawing office staff in all categories. The following are required urgently: Mechanical Draughtsmen. Instrumentation Draughtsmen, Electrical Draughtsmen. Preference will be given to candidates of Higher National Certificate standard and with at least two years' Drawing Office experience. The Company will train men of this standard who are interested in Instrumentation work if they lack experience. Appointments are to permanent staff and superannuated. Five-day/36-hour week. Recreation Club, etc. Housing assistance possible in approved cases. Write for application for employment form to Staff Officer, Imperial Chemical Industries Limited, Wilton Works, Middlesbrough, quoting advertisement reference ICI/X/215/r. W 3159

INSPECTOR required for small batch production of Electronic Equipment. Adequate technical knowledge and ability to work with minimum supervision. Excellent prospects for right person in expanding company. Rivlin Instruments Ltd., 7a Maitland Park Villas, London, N.W.3. GUL 2960. W 1344

INSTALLATION ENGINEER required by well-known manufacturers of mobile and fixed V.H.F. communications equipment. Excellent opportunities for advancement. Sound knowledge and experience necessary. Write giving full particulars to Sales Manager, British Communications Corporation Ltd., Exhibition Grounds, Wembley. W 3171

INTERMEDIATE & SENIOR DRAUGHTSMEN (24-30) required for Production Drawing Office. Applicants should have good mechanical background, together with some electronic knowledge. O.N.C. standard preferred. Applications in writing may be made in the strictest confidence to Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Ilford, Essex. W 3078

MANAGER REQUIRED for unit of a well-established Engineering Company engaged in large scale production of Radio and Television. The successful candidate will have a specialized knowledge of this class of work and will be capable of advising and supervising the Design Laboratories, Tool Design, Planning, and Machine and Assembly departments. This vacancy offers ample scope and opportunity to a man with high administrative ability. Salary up to £2,500 per annum. London Area. Please reply, in confidence, giving full details to Box No. W 3102.

McMICHAEL RADIO LTD., Slough, Bucks, have vacancies from time to time for Electronic Engineers to be engaged on Government projects. Those wishing to be considered are invited to write fully to the Chief Engineer, Equipment Division. W 205

MULLARD RESEARCH LABORATORIES invites applications from Honours Graduates to carry out research and development on the application of new magnetic materials to computers. Initially, the work will be concerned with digital storage and information-handling devices incorporating ferrite cores. Post-graduate experience in either computer techniques, transistors or magnetic devices would be an advantage. The work calls for a high degree of individual responsibility and there is great scope for initiative and inventiveness. Publication of results will be encouraged. Salaries are based on qualifications, experience and age, and are in keeping with present-day levels. General prospects within the organization are excellent. Applications to Mr. G. A. Taylor, Personnel Manager, Mullard Research Laboratories, Cross Oak Lane, Salfords, near Redhill, Surrey, quoting reference E.R.L. W 3188

MURPHY RADIO LIMITED have vacancies in the Electronics Division Laboratories for qualified engineers to design and develop the following:— 1. V.H.F. and U.H.F. Communications equipment. 2. Airborne and Ground radar equipment. 3. Computing devices and servo systems. 4. Nucleonic equipment and measuring instruments. 5. Transistors. The salary range is £600—£1,000 per annum depending upon experience. Further posts are available to engineers of H.N.C. standard or equivalent having less experience, the salary range being £450—£650 per annum. These vacancies are at Welwyn Garden City but one or two vacancies of a similar nature are available at the Ruislip Works. Applications, giving age, full details of qualifications, experience and salary required, should be forwarded to Personnel Department, Murphy Radio Ltd., Welwyn Garden City. W 3015

PHYSICIST or Physical Chemist required to control a process for the manufacture of carbon resistances. Candidates should be qualified up to degree standard and should preferably have had experience in the carbon black, synthetic resin, or electronic industries. The salary is in the range of £900-£1,200 per annum. Apply to the Plessey Company Limited, Caswell, Towcester, Northants. W 3234

PLANNING ENGINEER required for Electronics Division. Must be experienced in the production of radar, electronics and nucleonic apparatus and able to take responsibility for assembly line and plant lay-out. Apply stating age, qualifications and experience to Personnel Manager, E. K. Cole Ltd., Southend-on-Sea. W 3254

PYE LIMITED, Radio Works, Cambridge, invites applications for positions as Technical Authors and Illustrators for the compilance of Maintenance Handbooks dealing with radio equipment. Applicants must possess command of English and some technical knowledge. Applications in writing to Assistant Personnel Officer. W 3232

PHYSICISTS required for applied research on the microwave properties of ferrites at a laboratory pleasantly situated in Northamptonshire. Applicants should have an Honours Degree in Physics. Previous experience of microwave techniques an advantage but not essential. Box No. W 3140.

PYE TELECOMMUNICATIONS Ltd., Ditton Works, Cambridge, offer excellent opportunities for junior and senior Development Engineers in the electronics and communications field. Duties include development work on H.F., V.H.F., microwace and recording equipments. Applications are especially welcomed from persons possessing B.Sc., Higher National or Ordinary National Certificates. Good facilities are available, however, to keen young men wishing to train and study in these fields. Pleasant working conditions in modern factory. Single accommodation available. Write, giving fullest details to Personnel Manager. W 3144

PRODUCTION ENGINEER required by a large engineering organization situated in Southern England. Applications are invited from men with appropriate engineering qualifications and experience in the Electronic Engineering fields. The successful candidate will have extensive experience of administration, tool design, estimating and time and motion study, and will be acquainted with the most up-to-date production methods and techniques. He will have experience of small batch production of electronic equipment and/or light electro-mechanical precision instruments. For a man with the required qualifications, initiative and drive this vacancy provides excellent propects in a rapidly expanding organization. Please write, in strictest confidence, giving full details of experience, to Box No. W 3163.

PRODUCTION ENGINEER required for production of miniature electronic components and test gear. Ardente Ltd., 62 Horn Lane, Acton, W.3. W 3241

QUALIFIED PHYSICISTS and Radar Engineers required to study problems involving microwave propagation in conjunction with newly-developed materials. Previous radar experience essential. Box No. W 3142.

RADAR DEVELOPMENT. Engineers required for Research Laboratories situated at Dunmow, Essex. The work is of an interesting and varied nature concerning sea and air navigational projects and involves occasional trials. Recent experience in a similar or associated field of electronics is required, together with a technical background, preferably of at least Higher National Certificate standard. Salaries are in accordance with experience and qualifications but are based on a generous scale. The positions are permanent and favourable pension and payment during illness arrangements, etc. are in operation. There is ample scope within an expanding organization for personnel who are progressive and able to use their own initiative. Applications, which can be made in strict confidence, should include details of age, qualifications, experience and salary required, and be addressed to The Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex. W 3227

RTSC LABORATORIES. The joint research organization of Richard Thomas & Baldwins Ltd., and the Steel Company of Wales Ltd., invite applications for the following vacancy. Physics Department. Physicist for research work involving the application of physical techniques to the metallurgical problems of flat-rolled products. Some previous experience of industrial research in electrical measurements, instrumentation and electronics desirable. Applicants for the above post should be of degree or equivalent standard with some previous experience in the appropriate field. Applicants of lower academic standing with adequate previous experience will also be considered. The commencing salary will be in the range of £550-£800, depending on the qualifications, age and experience of the successful applicant. Inquiries should be addressed to the Director of Research, RTSC Laboratories, Whitchurch, Aylesbury, Bucks. W 1339

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

SCIENCE GRADUATE or equivalent required for development work on dielectrics. Knowledge of one or more of the following an advantage—statistical methods, polymers, electrical measurements, insulating materials. Very good prospects and conditions of service. Men interested to visit the works should write or telephone the Personnel Manager, for an appointment. Telephone Manufacturing Co. Ltd., Sevenoaks Way, St. Mary Cray, Kent. Orpington 26611. W 3053

SENIOR AND JUNIOR design draughtsmen required for interesting work in connexion with electronic equipment, commercial radio and television and/or light electro-mechanical engineering. London area. The positions vacant offer ample scope and opportunity for future advancement to men of good ability. A high salary will be paid to the selected candidates. All recognized staff privileges available. Please reply, giving full details of experience to Box No. W 3008.

SENIOR DRAUGHTSMEN. Due to expansion of the Electronics Division of the Plessey Company Limited there are several vacancies for experienced men in the following fields: 1. Design of a wide range of electronic equipment, including work to Service requirements. 2. Mechanical design of precision mechanisms for quantity production. These vacancies carry attractive salaries and long term prospects in reward for hard work and offer good staff conditions including superannuation and insurance schemes. Applications, which will be treated in confidence, should be addressed to: The Plessey Company Limited, Vicarage Lane, Ilford, Essex. W 3052

SENIOR ELECTRONIC ENGINEER required for a new development ancillary to the commercial use of large scale electronic computers, in the Leo products of J. Lyons & Company Ltd. The starting salary will be in the range of £800 to £1,000 p.a. according to qualifications and experience. Write giving full details to Control Office, Cadby Hall, London, W.14. W 3242

SENIOR ENGINEERS are required by The English Electric Co. Ltd., at Luton, to devise equipment and/or direct activities to investigate the effects of vibration and other environmental conditions on Guided Weapons. Experience in this field is unnecessary but applicants should possess a Degree or H.N.C. and preferably have had some experience in the Electronic Industry. Housing assistance can be given if required. Please write stating age, qualifications and experience to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. 1000G. W 3216

SENIOR METHODS ENGINEER required by a large and progressive Engineering Company situated in the London Area. Applications are invited from men with good engineering qualifications and experience in the manufacture of Radio, Television and Services Equipment. The accepted candidate will have extensive experience of this class of work and will be acquainted with the most up-to-date production methods, including work study and standard costs. For a man with the required knowledge, initiative and drive, this vacancy provides excellent prospects. Salary range from £800-£1,500 per annum. Please reply, in confidence, giving full details of previous experience to Box No. W 3104.

SENIOR SALES ENGINEER required by Telephone Manf. Co. Ltd., Martell Road, West Dulwich, London, S.E.21, with a minimum of 10 years qualified experience. Must have comprehensive knowledge of the use of polarized relays in the telecommunications, servo mechanisms, electronic circuits and allied applications. Pension and Staff Bonus Schemes after qualifying period. Write giving full particulars to Personnel Dept. W 3187

SENIOR TECHNICAL SALES REPRESENTATIVE with British Communications Corporation Ltd., Exhibition Grounds, Wembley. A new appointment to meet expanding commercial activities. Applicants should have sound general knowledge of V.H.F. communications equipment and have sales experience in this field. Some administrative skill also desirable. Write giving full personal history to the Sales Manager. W 3169

SENIOR TOOL DESIGN DRAUGHTSMEN. Applications are invited from Tool Design Draughtsmen who have served an engineering apprenticeship and have had at least five years' experience of Jigs and fixtures as applicable to the light mechanical engineering industry. The work is of an interesting nature, together with modern working conditions and offers excellent scope for advancement. Salary up to £700 per annum. London area. Please reply, giving full details of experience to Box No. W 3235.

SIEMENS BROTHERS & CO. LTD., require technicians for their Research Laboratories at Blackheath S.E.3, engaged in work on electronics and telecommunications. Pensionable staff posts with good prospects of advancement. Apply in writing to Siemens Brothers & Co. Ltd., Ref. 744/12, Woolwich, S.E.18, giving particulars of age, qualifications, training, experience and salary required. W 3047

SMITHS AIRCRAFT INSTRUMENTS have vacancies at Cheltenham for 2 Senior Engineers in their Engine Controls Laboratory for research and development on Gas Turbine electrical servo control equipment. Applicants, who should have a University Degree, A.M.I.Mech.E., A.M.I.E.E., A.F.R.Ae.S., or similar qualifications, must be capable of leading a small team, and have experience in, and a knowledge of one of the following: (a) Theoretical and/or practical aspects of servo mechanisms. (b) Electronics. (c) Magnetic amplifiers. These posts are permanent, and salaries will be within the range £1,000-£1,500. A Pension Scheme is available. Applications should be made to the Personnel Manager, S. Smith & Sons (England) Ltd., Bishops Cleeve, Cheltenham, quoting ref.: 56/EN. W 1322

SYSTEM TEST ENGINEER. An electronic engineer is required to assist in final tests on part of a missile system. Some theoretical knowledge useful but several years' practical experience necessary. Ex-Service wireless or radar technician with National Certificate of City and Guilds would be preferred. (Ref. 153). Write in detail, quoting Ref. No. to:— The Personnel Manager (Technical Employment), de Havilland Propellers Ltd., Hatfield, Herts. W 3186

TECHNICAL ASSISTANTS required for development of electromechanical and electronic instruments (Marine). Work involves initial experiments, sea-going trials, pre-production models and factory liaison. Occasional visits Overseas are arranged. Qualifications—Practical: 5 years' Workshop or Drawing Office experience. Academic: City & Guilds Telecommunications Finals Group Certificate, or equivalent. Applications, stating salary required, should be addressed to the Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex. W 3077

TEST ENGINEERS are required by a Leading Midlands Manufacturer for:— (1) Testing and Fault Finding on Radar Units and other Electronic Devices. (2) Construction and maintenance of Test Equipment. (3) Testing and Fault Finding on domestic Radio and Television Receivers. These progressive positions cover a wide range of activities and selection will be made not only on experience but also on ability to respond to further training. Ex-Service technicians are particularly suitable. Applicants should write, giving details of career to date and salary expected to the Personnel Manager. (Ref. GLB), Box No. W 3036.

TECHNICAL AUTHORS and Technical Illustrators are required for work on publications describing electronic and electrical instruments. Applicants must have had suitable experience in preparation of instrument manuals and in knowledge of A.R.B. requirements. Apply Personnel Manager, Smiths Aircraft Instruments Ltd., Bishops Cleeve, Near Cheltenham, Gloucester, quoting reference 58/EN. W 3183

TECHNICAL WRITERS. A well-known electronic and aircraft servo manufacturer located in the West London area invites applications from experienced Technical Writers for positions in the Engineering Division of the Company. The work would involve the compilation of technical instruction and maintenance manuals covering a wide range of equipment. Primary qualifications would include a good engineering background in the field of electronics and a marked ability to write clear and essentially readable technical information. Some knowledge of the requirements for Service documentation would be an advantage. The appointments are of an interesting nature and offer permanent employment with good working conditions. A pension scheme is in operation. Write, giving full details of experience and indicating salary required, to Box No. W 3221.

TEST GEAR Design Engineers and Maintenance Engineers required with practical experience of this class of work, based on sound knowledge of electronic principles. These vacancies are permanent and progressive. A company pension scheme in operation. London area. Please write, in confidence, giving full details of qualifications to Box No. W 3165.

THE BRITISH THOMSON-HOUSTON Co. Ltd., Leicester. Vacancies exist in the Electronics Engineering Department at the Blackbird Road (Radar) Factory for Engineers as follows:— 1. Senior Engineer with at least 4 years' experience in engineering for production. 2. Junior Engineers for work as above; training will be provided in development/design/factory liaison work for junior engineers interested in this class of work, and with suitable qualifications. Applications stating age and giving details of experience and qualifications to:— The Manager, Electronics Engineering Dept., British Thomson-Houston Co. Ltd., Rugby. W 3155

THE BRITISH THOMSON-HOUSTON CO. LTD., Rugby. Because of expanding commitments, the company wishes to increase its development Engineering staff engaged on Radar and associated fields of activity. Requirements:— (a) One senior engineer for each of the projects enumerated below. Qualifications:— Graduate or equivalent status with several years' experience. (b) Junior engineers, graduate or H.N.C. preferably with some relevant experience, for whom training will be provided where appropriate. 1. Complex microwave systems involving the use of new types of valves and circuit elements. 2. Microwave component developments, with special reference to novel techniques of manufacture. 3. Microwave aerial and feed systems. 4. High power pulse generating. 5. Intermediate frequency amplifiers, switches, and special circuit developments. 6. Circuit and system development associated with display and data extraction systems. Mechanical Engineer. A qualified mechanical engineer is also required, for development/design of large precision mechanical structures in connexion with new types of ground radar. Experience with gear-drive is desirable. Applications stating age and giving details of experience and qualifications to:— The Manager, Electronic Engineering Department, The British Thomson-Houston Co. Ltd., Rugby. W 3167

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

THE BRITISH THOMSON-HOUSTON Co. Ltd., require a Physicist or an Electrical Engineer in their research laboratory at Rugby for work connected with the development of new types of electric lamp. In addition to the determination of the Physical design and measurement of electrical and optical characteristics, the work involves the development of the associated circuitry which is often of special nature. Applicants are invited to send particulars of their qualifications to the Director of Research, British Thomson-Houston Co. Ltd., Rugby, quoting reference BE. W 3114

THE BRITISH THOMSON-HOUSTON Co. Ltd., require graduate engineers and Physicists for the design construction and processing aspects of magnetron and other electronic valve developments. The work is carried out in close association with a small machine shop and pilot production unit and every encouragment is given to the development of new ideas. It is work in which both practical and theoretical interests are desired. Applicants should write to the Director of Research, British Thomson-Houston Company Ltd., Rugby, giving their age, qualifications and experience and quote reference FT. W 3115

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Allesley, Coventry, requires Mechanical Development Engineers, Designer-Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments for work on Guided Weapons and like projects. Also required, Senior and Junior Electronic Development Engineers, particularly in the field of Microwave and Pulse Applications. Salary according to age, qualifications and experience. Apply by letter stating age and experience to the Personnel Manager. Ref. R G. W 208

THE BRITISH THOMSON-HOUSTON CO. LTD., Rugby. The following vacancies exist for development engineers in the field of industrial Electronics and related work, concerning application of modern methods of control to industrial processes. In each division enumerated below a senior engineer is required of graduate status with several years' experience. Suitable Junior engineers with at least H.N.C. or equivalent qualification, with some industrial experience will be considered for training. The company has a wide background in this field together with many commercial electronic projects allied with the heavy engineering business of the B.T.H. Company. 1. Electronic-Motor Control: Development and application engineering of Electronics for the control of rotating machinery, for a variety of Industrial drives: viz. Machine-tools, textile machinery, printing presses. paper-making, etc. 2. Magnetic Amplifiers: Development and application of these and related non-linear ferromagnetic devices. 3. Servo Systems: Development of servos mainly of Power Ratings for military and industrial applications. 4. Factory Automation: Development of co-ordinated schemes of automatic control for machine-tools and other factory equipment. 5. Welding Control: Engineering and development of electronic control apparatus for resistance welding. Application Engineering associated with the foregoing. 6. Industrial Communication Equipment: Development and circuit design of audio and carrier types of apparatus. Project and field engineering of comprehensive Industrial communication systems. While knowledge of of electronic control is desirable, applications are invited from engineers with application experience, not necessarily electronic, in connexion with 1, 3, 4 and 5 above. Applications stating age and giving details of experience and qualifications to:— The Manager, Electronic Engineering Department, British Thomson-Houston Co. Ltd., Rugby. W 3168

THE BRITISH THOMSON-HOUSTON Co. Ltd., has a vacancy in its Research Laboratory at Rugby for a qualified Electrical Engineer or Physicist for work on radio interference problems. The work covers investigation of the mechanism, measurement and suppression of radio interference over a wide and interesting range of sources. Applicants should write to the Director of Research, British Thomson-Houston Co. Ltd., giving their age and qualifications, and quoting the reference RIS. W 3199

THE G.E.C. STANMORE LABORATORIES invite applications for the following vacancies: 1. Circuit engineers to fill several vacancies in our engineering development Laboratories. The group is responsible for developing production prototype models of equipment for the services. including items such as: I.F. Amplifiers, Video Amplifiers, Pulse Manipulating Circuits. D.C. Amplifiers, Magnetic Amplifiers, Power Packs. (Ref. EE/MW.1). 2. Microwave Engineers for work on transmitter receiver equipment for guided weapons. The vacancies are in laboratory teams engaged on engineering development for production. (Ref. EE/MW.2). All the above posts are for experienced engineers. There are, however, a limited number of vacancies for men who are studying for H.N.C. or equivalent qualification. 3. Trials Staff for several posts at levels appropriate to H.N.C. and Honours Degree standard for work on Radar Type Equipment. In some cases an ability to carry out theoretical assessment would be an advantage. Some interest in flying and aircraft is desirable. Service qualifications of appropriate standard considered. (Ref. EE/JMCP.1). 4. Engineers to fill vacancies in a recently formed Special Development Section working on: (a) Electronic Equipment Design AR/BAT.1/EE. (b) Light Electro Mechanical and Hydraulic Servo Development AR/BAT.2/EE (c) General Radar Electronic Development AR/BAT.3/EE. Applicants for Senior Posts should have a sound electrical or mechanical background preferably with academic qualifications in Electrical/Mechanical Engineering or Physics. and those for Junior Posts should have obtained H.N.C. Electrical. 5. Experienced Physicist and/or Electrical Engineer to work on Circuitry and servo design aspects of Radar Equipment. (Ref. EE/SM). Please apply in writing to the Staff Manager, G.E.C. Stanmore Laboratories, The Grove, Stanmore, Middlesex, quoting the appropriate reference number. W 3178

THE MULLARD RADIO VALVE CO. LTD. has a number of vacancies for Electrical Engineers or Physicists to undertake Applied Research Work in the applications of transistors and kindred devices. The field offers opportunities for original work and at times requires considerable ingenuity. Further advanced studies and publication of results is encouraged. It is intended that the posts will eventually carry considerable technical responsibility in an expanding organization. For this reason applicants should possess a good Honours degree and some previous experience or, alternatively, a real interest in electronics would be an advantage. Commencing salary will be according to individual qualifications and experience and will provide progressive remuneration for increased responsibilities. Applications in writing, which will be treated in confidence, should be addressed to Personnel Officer, The Mullard Radio Valve Co. Ltd., New Road, Mitcham Junction, Surrey, quoting ref.: JFG/H.1. W 3170

THE TELEGRAPH CONDENSER CO. LTD., invite applications from Engineers fully experienced in Radio and Television design to assist Chief Development Engineer in development of printed circuits. Qualifications at least to A.M.I.E.E. standard. This position offers scope for the right man who must be capable of initiating and following projects to finality, including contact with customers. Superannuation scheme. Write giving full details of qualifications and experience. age and salary required, to Personnel Manager, T.C.C. Ltd., North Acton, W.3. W 2932

THE TELEGRAPH CONDENSER CO. LTD., require Radio and TV Engineer with laboratory experience for work in connexion with printed circuits. H.N.C. standard. Superannuation scheme. Write giving full details of education and experience, age and salary required to Personnel Manager, T.C.C. Ltd., North Acton, W.3. W 2933

URGENTLY REQUIRED single young men as Electronic Wiremen, assemblers and fitters, a'so Junior and Senior Test Engineers in connexion with Television Cameras and ancillary equipment. Apply in writing to Personnel Office, Dept. 24, Pye Ltd., Radio Works, Cambridge. W 3145

VICKERS-ARMSTRONGS Ltd., (Aircraft Division) require for their Guided Weapon development department: (d) Technical writer (electronic) for compiling publications on Guided Weapons. Applicants should have a sound electronic and preferably also mechanical background together with the ability to write concise English. This is a new post offering good prospects. Applications, which will be treated in confidence, should state age, qualifications and experience. Applications, quoting date and prefix letter of advertisement, to: Employment Manager, Vickers-Armstrongs Limited (Aircraft Division), Weybridge Works, Weybridge, Surrey. Weybridge is 30 minutes from London on the main Waterloo/Portsmouth line. Additional buses operate to and from the Works at starting and finishing times. Canteen facilities. Applicants should be in a position to arrange their own housing accommodation. Assistance can only be given with individual lodgings. W 3189

YOUNG MEN required for assembly, wiring and testing of Electronic apparatus. Some experience with scientific instruments an advantage. Technical School education. Must have completed National Service. Pension scheme, five-day week, canteen. Camden Town district. Salary according to age and experience. Please apply, stating age and experience, to Box No. W 3148.

Further "Situations Vacant" advertisements appear in display form on pages 81, 98, 106. 108, 115, 116, 129, 132, 137 and 139.

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COPIES of Electronic Engineering published before October 1954. Box No. W 3224.
WANTED high speed double beam oscilloscope. Price and full details to Box No. W 1343.

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IMMEDIATE CAPACITY available for coil, armature and stator winding, assembling and wiring of control panels. Electric Windings (London) Ltd., 2a Whites Row, Spitalfields, London, E.1. Phone: Bishopsgate 3149. W 1342
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PRESSINGS IN ALL METALS up to 60 tons. Press tools manufactured in our own tool-room. Light assemblies — Domestic, Electrical and mechanical. All finishes. A.I.D. and A.R.B. approved. Advice and Estimates given free. Inquiries to Metal Components Ltd., Dolphin Road, Shoreham-by-Sea, Sussex. Telephone: Shoreham 2224/5. W 1298

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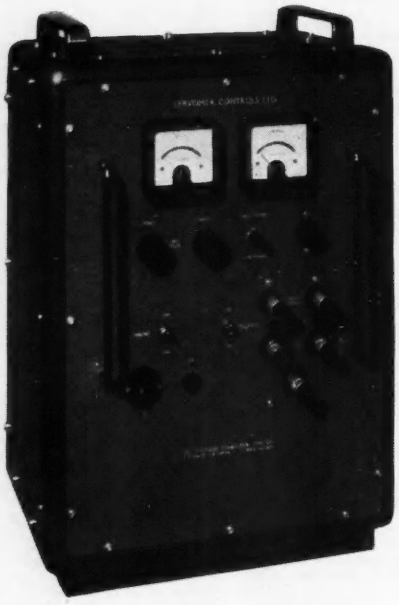

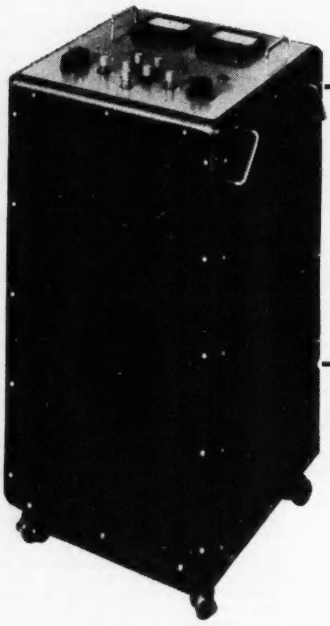

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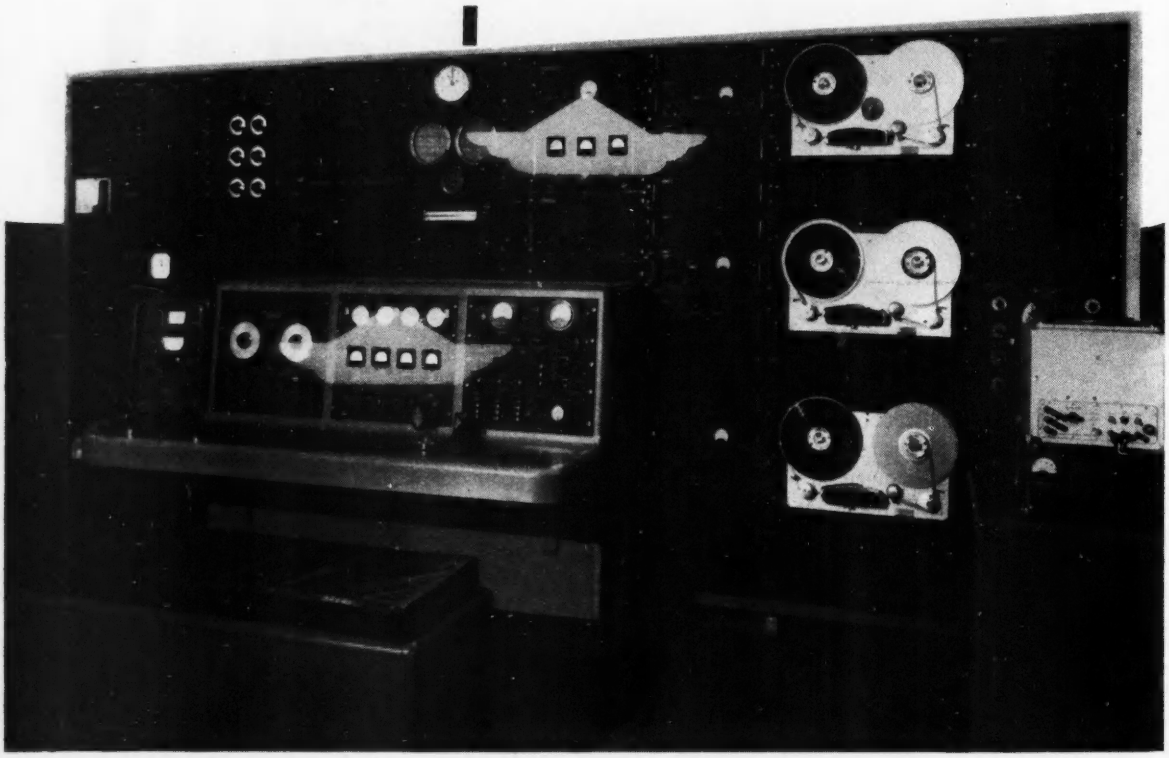

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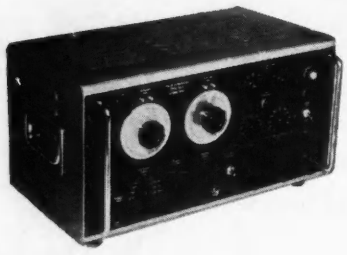

NEW!

Pulse Generator

TYPE 104A

ABRIDGED SPECIFICATION

1. Input Triggering

Either (a) positive or negative pulses or sine waves. Trigger sensitivity approx. 10V peak. Or:
(b) internal trigger generation, continuously variable from 10 c/s to 100 Kc/s.
The above facilities are selected by a 3-position switch.

2. Output

quare topped +ve or −ve pulses, direct or A.C. coupled. Output from D.C. terminal arranged such that most positive portion of the waveform is at earth potential.

3. Voltage Range

(a) Direct or A.C. coupled:—0·1 to 51 volts switched, plus a continuously variable 0 to 0·1 volts. Incremental accuracy ±2%. Absolute accuracy ±5%.
(b) Attenuated and A.C. coupled:—0·1 to 11 volts switched, plus a continuously variable 0 to 0·1 volt. Attenuation by factors 10, 100 and 1000, giving switched amplitude range of 100 micro-volts to 1·1 volts plus variable control. Incremental accuracy ±3%. Absolute accuracy ±5%.

4. Duration

Continuously variable 4 to 500 micro-secs.
Accuracy ±5%.

5. Output Impedance

(a) Direct and A.C. coupled:—22Ω per volt for voltages above 1 volt. Less than 22Ω for voltages less than 1 volt.
(b) *Attenuated A.C. coupled output.*

Output	*Impedance*
+ 10	2200Ω
+ 100	220Ω
+ 1000	22±

6. C.R.O. Trigger

A pulse coincident with the leading edge of the output pulse is available for the triggering of a monitoring oscilloscope.
Amplitude 16V −ve. Duration 2 micro-secs.

A new general purpose Pulse Generator, featuring a decade amplitude control with high incremental accuracy. This instrument is particularly useful for testing sensitive pulse amplitude discriminators as used in the field of nuclear particle counting, or in any application where a stable output is required.

Operation is from 200-250V or 110-125V, 40-60 c/s supplies.

ELECTRONIC NUCLEONIC INSTRUMENTS

Further details concerning the Type 104A and other instruments available on application

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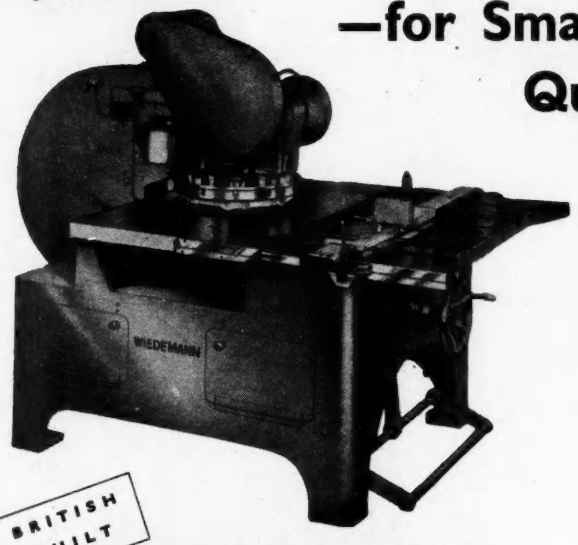


BRITISH BUILT

WIEDEMANN

Type RA-41P

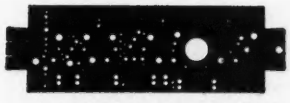
TURRET PUNCH PRESSES

give lower production costs
—than by any other method

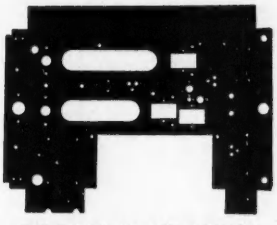
The RA-41P combines the versatility, accuracy and high speed of the pantograph for rapid hole location, with the time saving features of the WIEDEMANN Turret Punch Press for quick punch and die selection. Up to 20 low cost punches can be set up in the turret ready for instant use.

Maximum sheet size	28 in. x 40 in.
Throat depth	28 in.
Capacity	15 tons
Punching Capacity ...	3" diameter in .074" thick Mild Steel
	2" " " $\frac{1}{2}$" " " "
	$1\frac{3}{16}$" " " $\frac{3}{16}$" " " "
Strokes per minute	175

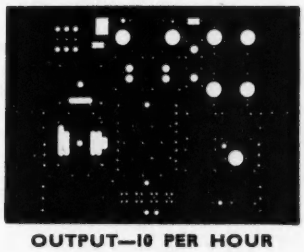
SHEET AREA UP TO 28" x 40"



OUTPUT—18 PER HOUR



OUTPUT—15 PER HOUR



OUTPUT—10 PER HOUR

ALL OPENINGS PIERCED IN TIMES SHOWN

The WIEDEMANN range includes small hand-operated models up to large power-operated machines of 80 tons capacity, capable of piercing 6" holes in $\frac{1}{4}$" plate.

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The Dalic Process of Electrodeposition

Renovating the zinc protective coating of a propeller blade on site at Air France

Characteristics of Dalic Deposits

Deposit	Brinell hardness of deposits	Time to deposit 0.0001 in. (sec.)
Bismuth	50	7.6
Cadmium	40	2.5
Chromium	600	63
Cobalt	250	7.6
Copper	150	2.5
Gold	100	6.2
Indium	<1	2.5
Iron	175	10.2
Lead	20	3.8
Nickel	500	5.1
Platinum	200	17.5
Rhodium	500	70
Silver	60	5.1
Tin	1	2.5
Zinc	70	3.8

The DALIC PROCESS of Electrodeposition provides a wide range of coatings on to most basis materials, including aluminium. It is particularly suitable for plating selected areas without stopping-off, for on-site work, and for plating assemblies or components which may not be immersed in plating solutions.

For such non-decorative purposes as building-up worn or overmachined parts, the extremely high speed of deposition and the accuracy with which deposit thickness can be controlled are most attractive features. Deposits are characterised by low stress, extremely fine grain, perfect adhesion and complete absence of porosity.

The DALIC PROCESS has received favourable acceptance by industry and recent installations have been made in the electronics, motor car, radio and television and armaments industries, in the Ministry of Supply, and in various research establishments.

also...

Electroplaters in all metals

including

- Internal plating of tubes, petrol tanks and pipes
- Heavy silver and rhodium plating for industrial purposes
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We welcome the difficult jobs; our business is the solving of your electroplating problems. Fully equipped laboratory for tests and analyses.

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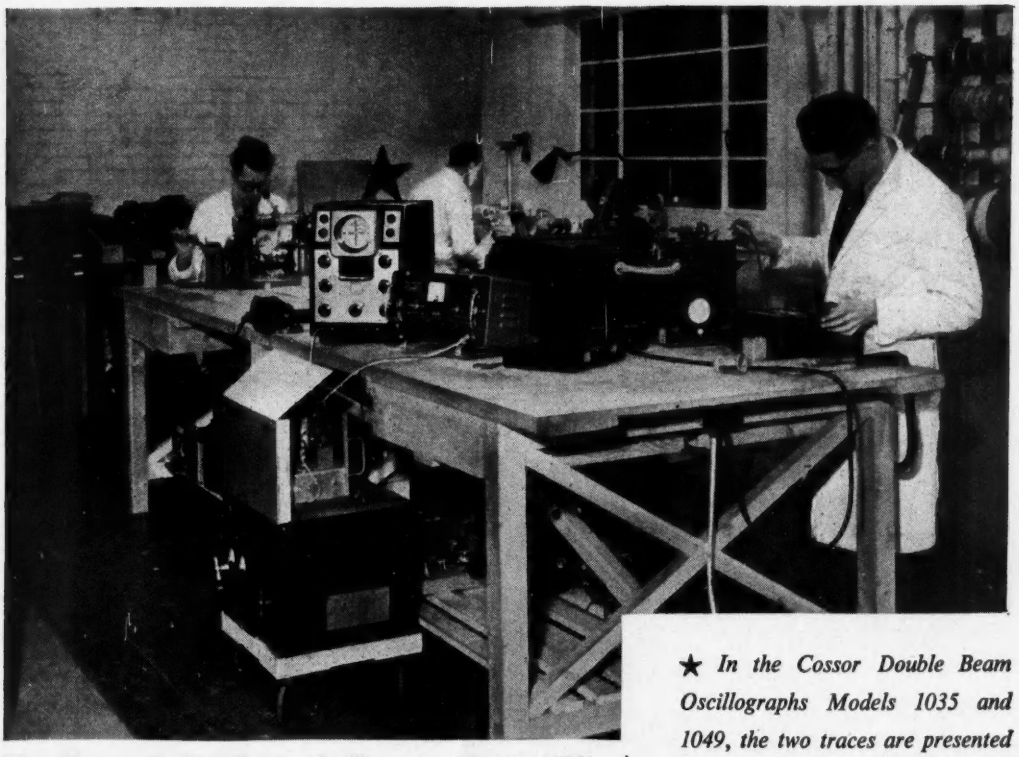

The Cossor Double Beam Oscillograph Model 1035 in use in the Research laboratories of Saunders-Roe Ltd., the famous flying boat manufacturers.

In displaying the mutual effect of two related and variable quantities simultaneously the Cossor Double Beam Oscillograph is solving many of the fundamental problems with which the Research and Development scientist is constantly beset. In the Production field, too, there are innumerable problems capable of complete solution by this versatile instrument and every branch of industry is realising the enormous potential of this apparatus in the detection and analysis of faults and the accurate monitoring of manufacturing processes.

The technical advisory staff of the Instrument Division is always at your service to help with your particular problem.

★ *In the Cossor Double Beam Oscillographs Models 1035 and 1049, the two traces are presented on a flat screen of 90 mm. dia., and the amplifiers are so calibrated that measurement of the voltage input as well as the time interval between various significant portions of the oscillogram is made possible. Permanent records for subsequent analysis may conveniently be made by attachment of Cossor Camera Model 1428, for which there is also a nine-speed Drive Unit Model 1431.*

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Please address enquiries to CI.68

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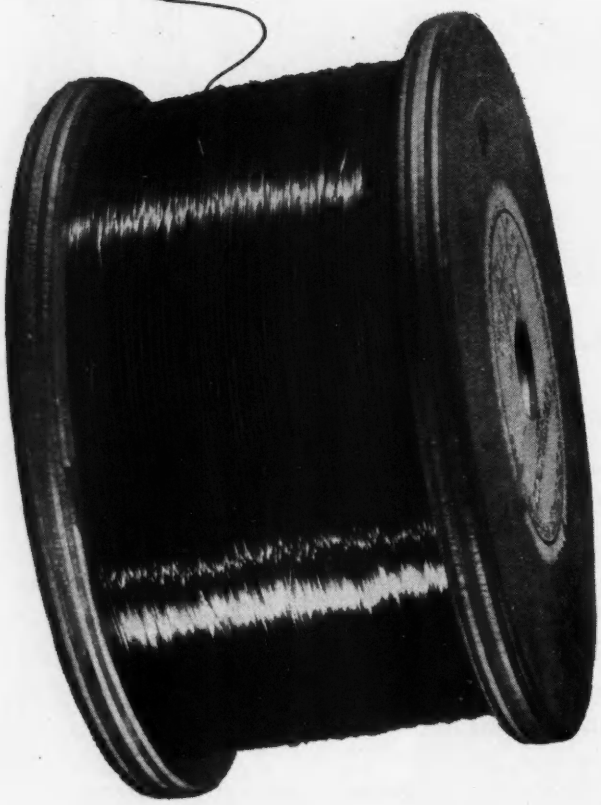
ENAMELLED WINDING WIRE



SEVERAL YEARS' RESEARCH lies behind the introduction of the new silicone wire enamel MS 1360. It has the toughness, flexibility, solvent resistance and adhesion expected of modern wire enamels and in addition has *outstanding heat stability.*

Accelerated life testing of electric motors wound with MS 1360-enamelled wire and insulated with silicone-bonded (Class H) components indicates that such motors, when operated at an average copper temperature between 160°C and 180°C, have a life comparable to Class A insulated motors operated within their normal temperature limits.

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Information about suppliers of wire and silicone insulating components is contained in Silicone Notes C 19, obtainable on request from:

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first *in British Silicones*

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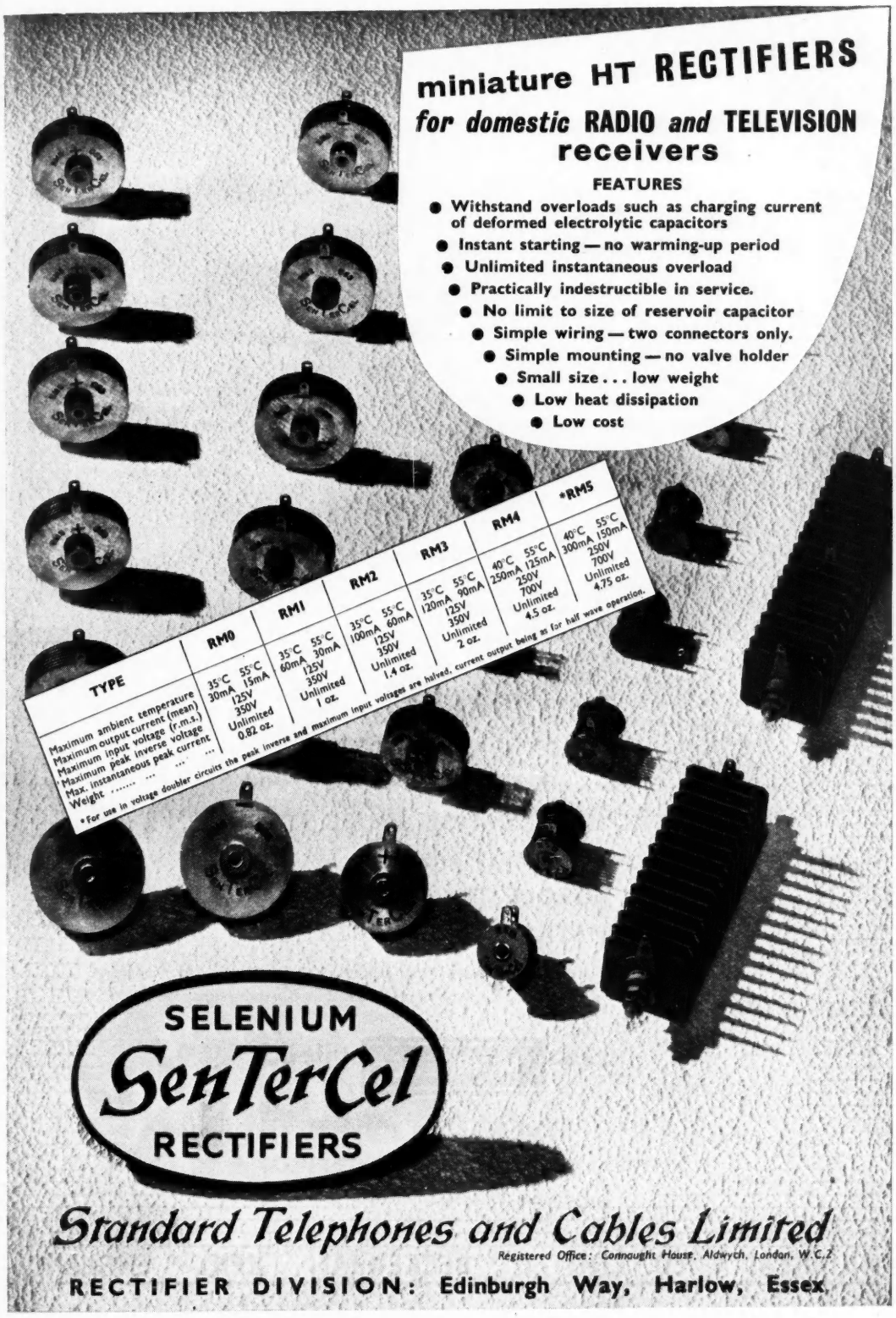
TSW MS 43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for domestic RADIO and TELEVISION receivers
FEATURES
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● Practically indestructible in service.
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TYPE | RM0 | RM1 | RM2 | RM3 | RM4 | *RM5
Maximum ambient temperature | 35°C 55°C | 35°C 55°C | 35°C 55°C | 35°C 55°C | 40°C 55°C | 40°C 55°C
Maximum output current (mean) | 30mA 15mA | 60mA 30mA | 100mA 60mA | 120mA 90mA | 250mA 125mA | 300mA 150mA
Maximum input voltage (r.m.s.) | 125V | 125V | 125V | 125V | 250V | 250V
Maximum peak inverse voltage | 350V | 350V | 350V | 350V | 700V | 700V
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Weight .... | 0.82 oz. | 1 oz. | 1.4 oz. | 2 oz. | 4.5 oz. | 4.75 oz.
*For use in voltage doubler circuits the peak inverse and maximum input voltages are halved, current output being as for half wave operation.
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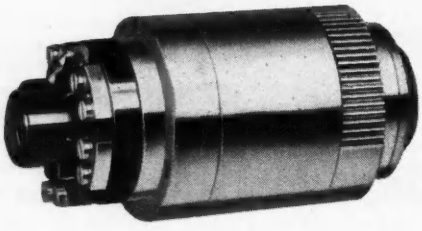

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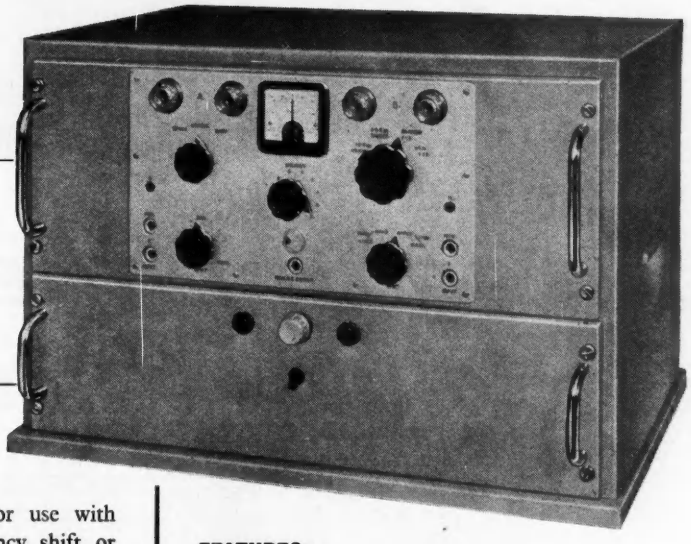
MUIRHEAD & CO. LIMITED · BECKENHAM · KENT · ENGLAND

Marconi Double Diversity Telegraph Recording Unit

TYPE HU.12



Shown here is the HU.12, in the bench mounting cabinet where it fits on top of the power unit. It can also be built into a standard rack which houses the associated receivers.

The HU.12 unit is designed for use with two suitable receivers of frequency shift or on-off telegraph transmissions in double diversity. The combined AF outputs of the receivers are converted into double current signals to operate an undulator, relay or other 'space-mark' type of equipment requiring a current up to 30 mA. No receiver modification is necessary except, perhaps, adjustment of the BFO frequency.

Satisfactory recording is possible should the first oscillator drift up to ± 800 c/s.

FEATURES:-

- **Electronic path diversity selector for FSK will function when difference between paths exceeds 4 db.**
- **Alternative DC output suitable for a low resistance undulator (20+20 ohms) is provided.**
- **Neon indicators for visual tuning of FSK reception.**
- **Front of panel control for pre-set 'mark' and 'space' current adjustment, filter selection and signal bias.**

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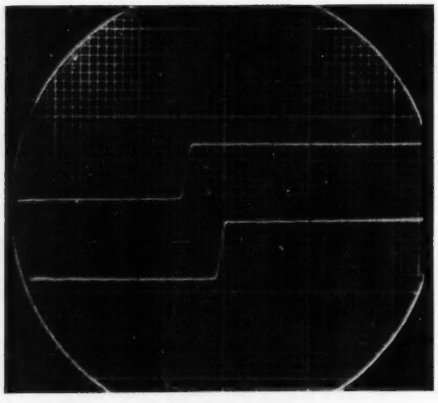
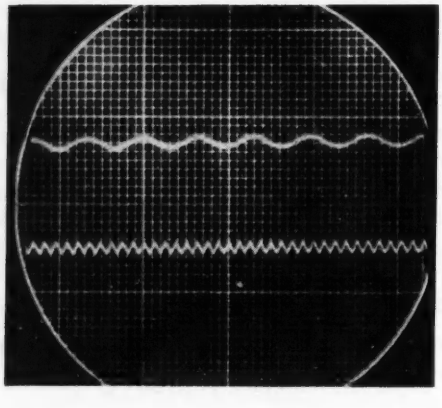
Partners in Progress with The **'ENGLISH ELECTRIC'** *Company Limited* LC 13

DE103 Square Wave leading edges at 2"/μsec illustrating rise times.



Leading the way to new Knowledge

DT103 20μV RMS applied to both channels at 100,000 gain showing noise level. Upper trace expanded X5.



NAGARD LTD TWO CHANNEL D.C. OSCILLOSCOPES

The latest in the NAGARD range, these two instruments embody entirely new facilities for the display and measurement of simultaneous phenomena.

MODEL DE103 is the first **WIDE BAND D.C. OSCILLOSCOPE** to provide a bandwidth of D.C.—10 Mc/s (—3db) and a **rise time of 0.035μsec in two identical channels.** Two separate gun systems stop interaction, while a 6 in. diam. CRT gives large and easily viewed traces with very fine detail.
Independent X shifts enable traces to be aligned as desired.
Calibrated for time and voltage measurements to 5 per cent.

MODEL DT103 is the first double-beam **D.C. OSCILLOSCOPE** with a **maximum sensitivity of 250μV/cm** in two identical amplifying channels. High stability with lowest possible noise level means that the high gain is really usable.
A wide range Time Base with reliable and sensitive triggering circuitry, X amplifier, beam blanking switch, and ×5 differential or dual-sweep expansion confer versatility in dealing with an infinite variety of signal conditions.
Bandwidth D.C.—100 Kc/s (—3db) fully calibrated for time and voltage measurement to 5 per cent.

Both instruments are easy to use, reliable, made to very high standards and are now in production.

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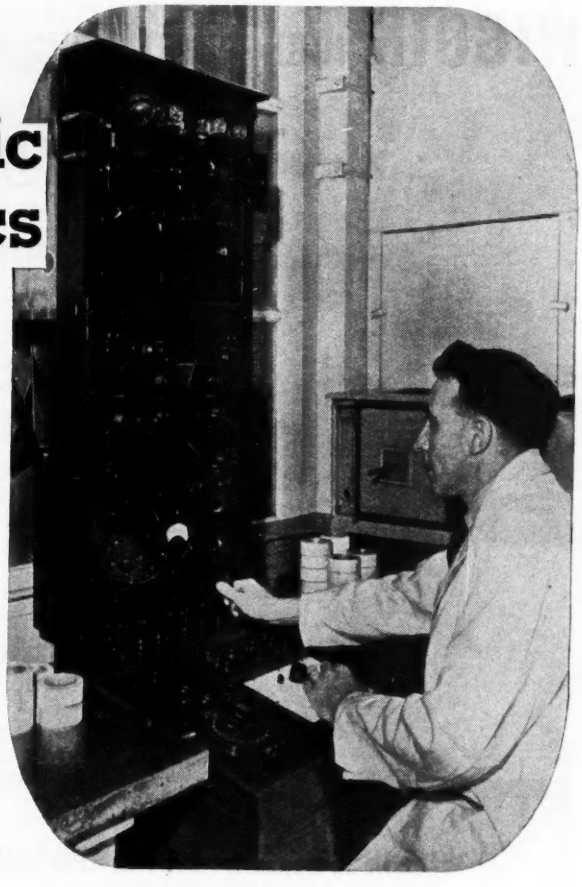
good magnetic characteristics *demand* PRECISE ELECTRICAL INSPECTION



Standard **maintains its established leadership in the manufacture of high permeability magnetic alloys by constant vigilance in the control of each and every production process, one of which is illustrated here. Produced by a Company which has the unique advantage of being a large-scale user of its own magnetic materials, a long experience of the applications of these materials gives full appreciation of the properties essential for uniform electrical characteristics and stable performance.**

It will pay you to investigate the capabilities of ***Standard*** **magnetic alloys with relation to your specific requirements.**

- PERMALLOY 'C' for highest initial permeability, useful for wide-band frequency transformers, current transformers, chokes, relays and magnetic shielding.
- PERMALLOY 'B' has lower initial permeability than Permalloy 'C' but higher values of flux density. Suitable where high permeability to alternating field is required superimposed upon a steady polarising field.
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by POWDER METALLURGY

The application of powder metallurgy to the production of wrought nickel alloys has been found to offer a number of advantages, especially in the very close control of composition and high level of purity which can be maintained. Nickel and nickel alloys produced by this means are of particular value in the electronics industry in meeting requirements which call for very stringent specifications of properties.

Materials produced by powder metallurgy are available in the form of strip, rod, wire and tube.

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High purity nickel for thermionic valve construction, etc.

CONTROLLED-EXPANSION (NICKEL-IRON) ALLOYS
Alloys for glass-to-metal seals with stringent expansion tolerances.

MAGNETIC (NICKEL-IRON) ALLOYS
High permeability alloys with improved and consistent properties.

Write for a copy of our leaflet
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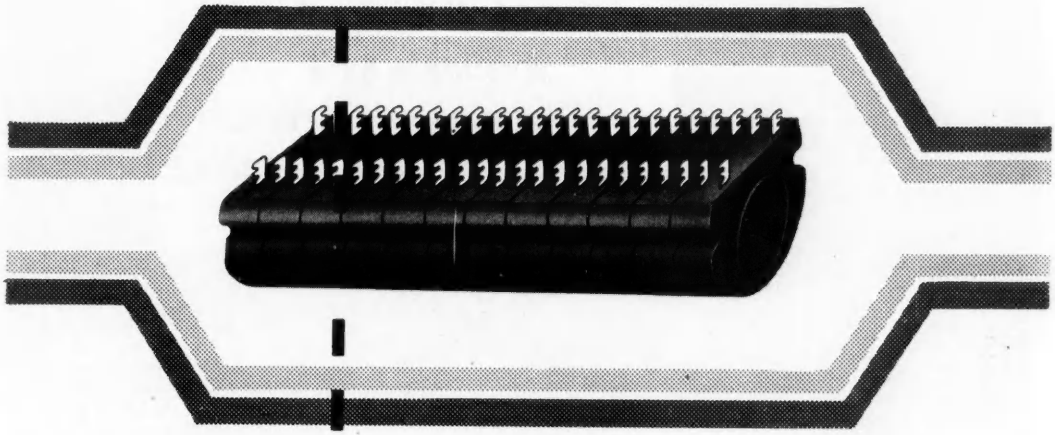
HENRY WIGGIN & CO. LTD., WIGGIN STREET, BIRMINGHAM, 16

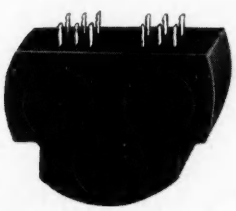
EL2

Loading coils **inside** the cable splice



The advantages of the splice loading technique are particularly marked in the loading of small cables of up to 74 pairs. The coils can be included in a jointing sleeve or unit of only slightly larger diameter than would normally be used.

The loading coils in the Mullard L.160 Series are designed specifically for this technique. They are cast in resin, which provides complete protection from climatic conditions and allows a telephone administration to store them ready for building into loading units as and when required. Both single and triple assemblies are available for different sizes of cable.



TRIPLE COIL ASSEMBLY

Ferroxcube pot cores give these coils certain electrical advantages over conventional types, particularly in the loading of higher frequency circuits such as those encountered in programme and carrier applications.

You are invited to write for leaflets describing the Mullard L.160 Series coils and simple units for pole and splice loading.

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MAGNETIC TAPE RECORDER

SERIES Y.D.

**** Available as a portable instrument or for rack mounting***

TAPE SPEEDS : 1⅞″ & 3¾″ p.s.
3¾″ & 7½″ p.s. 7½″ & 15″ p.s.

ABRIDGED SPECIFICATION

TRACK WIDTH. ·1″ displaced to one edge.

PLAYING TIME PER TRACK. Large reel (1,750ft.) 45 mins. at 7½″ p.s. Other speeds pro rata.

"WOW" AND FLUTTER (as change in tape velocity). Less than ·2% at 7½″ p.s.

LONG-TERM SPEED STABILITY (for 50 cycle mains input). Better than ·5%.

INPUT LEVELS FOR FULL DEPTH RECORDING. Input 1-1 megohm, min. signal ·003v. peak. Input 2-600 ohms, balanced, min. signal ·14v. peak.

OUTPUT ARRANGEMENTS. 15 ohm internal elliptical speaker. 15 ohm unbalanced socket output. 600 ohm balanced output (P.O. Gauge B jack).

SIGNAL TO NOISE RATIO (tape to spec. WW372/49). In the range 200 cycles to 12 Kc/s, better than 50 DB. Unweighted, including hum, 45 DB.

WORKING VOLTAGE. 100-120v. and 200-250vA.C.

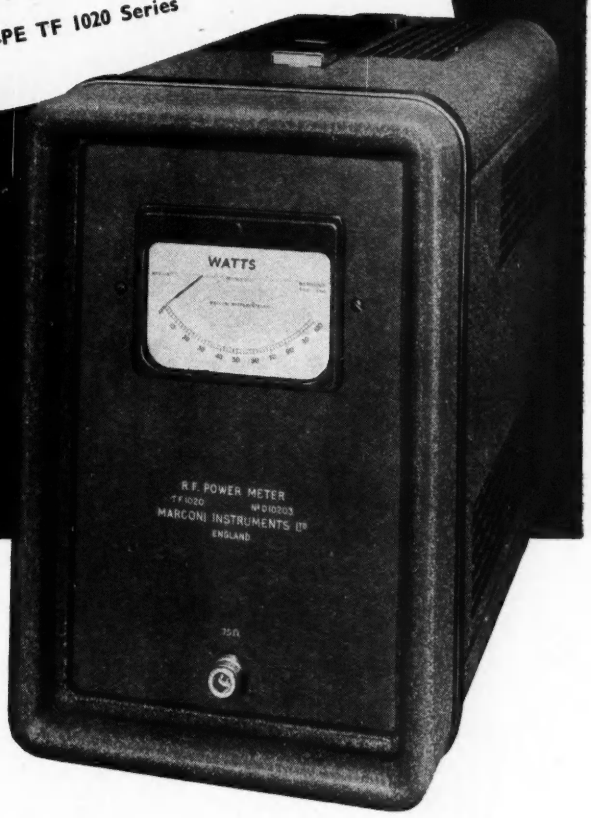
OVERALL DIMENSIONS. 18¼″ x 17½″ x 9¾″ high, with lid.

WRIGHT & WEAIRE LIMITED

131 SLOANE STREET · LONDON · S.W.1 Telephone: SLOane 2214/5 and 1510

TWO *New* MARCONI R.F. POWER METERS

TYPE TF 1020 Series



POWER RANGE
0 to 100 Watts

FREQUENCY RANGE
D.C. to 250 Mc/s

Both instruments have a linear power scale and accurately register mean power input regardless of waveform. The TF 1020 has an input impedance of 75 ohms; The TF 1020/1, an input impedance of 50 ohms.

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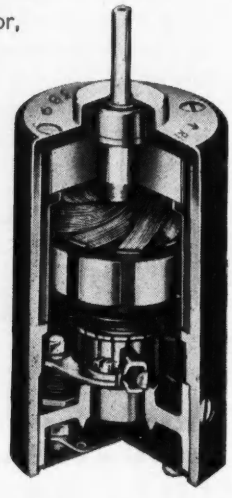
Vactric produce eight types of permanent-magnet motor, with 200 variations of characteristics to choose from.

Output	6.9×10^{-3} h.p.
Torque	100 gram centimetres 1.39 ounce inches
Speed	4500-5500 r.p.m.
Voltage	26 volts D.C.
Amps	0.58 amperes
Watts	15.2 watts
Rating	10 minutes



Telephone Sloane 9656 or write for brochure or technical assistance

Vactric Limited 196 Sloane Street London SW1

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ELECTRONIC DEVICES

OF INTEREST to all engineers, this new publication forms an invaluable reference to current G.E.C. electronic products suitable for such industrial applications as control instruments, scientific measurement, counting, radio-active indication, photoelectric alarms and indicating devices and electronic relays and voltage stabilisation. The technical information which includes ratings, dimensions, base connection diagrams and screen characteristics, enables the potential user to choose the device most suitable for a particular application.

The contents include:

- Barretters
- Cathode ray tubes (instrument and special types)
- Electrometer valves
- Geiger Muller tubes
- Photoelectric cells
- Photoelectric industrial aids
- Semi-conductors
- Voltage stabilisers

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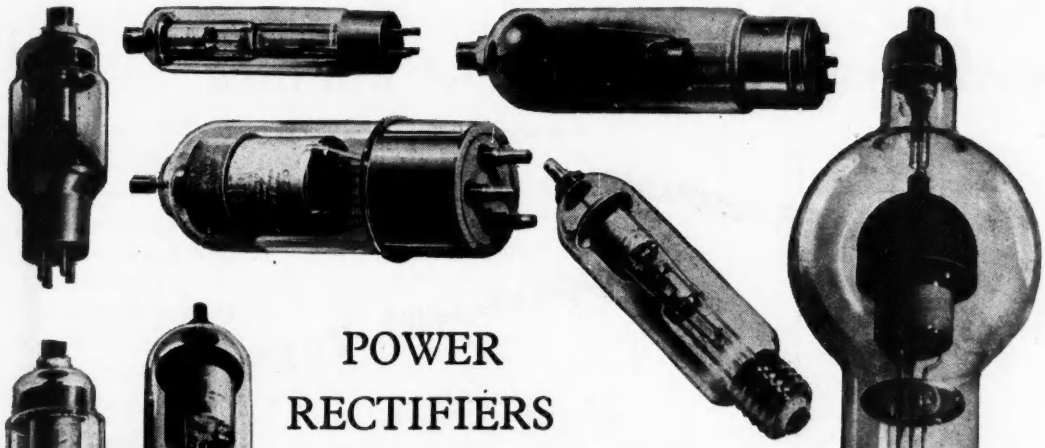
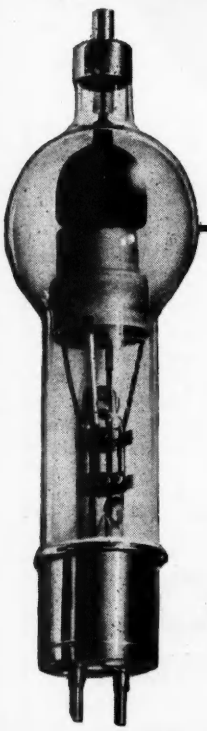
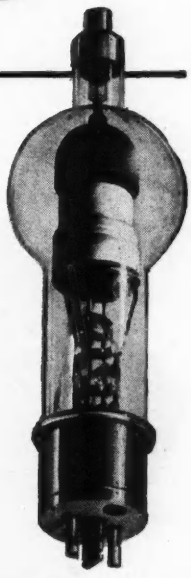


POWER RECTIFIERS

These Mercury Vapour and Xenon filled power rectifiers are robust and can be relied upon for long and satisfactory service. The output table shown herewith is calculated for a three-phase, full wave arrangement. Full technical data and operating instructions are available on request.



Tube Type	C.V. No.	Filling	Output in Kilowatts
AH 200	CV 1628	Mercury Vapour	90
AH 213	—	" "	90
AH 201	—	" "	7·5
AH 205	CV 2673	" "	630
AH 211	CV 532	" "	90
AH 221	CV 5	" "	36
AH 217	—	" "	36
AX 224	CV 1835	Xenon	7
AX 228	—	"	36
AX 230	CV 2518	"	36



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Waterhouse Lane, Chelmsford
Telephone: Chelmsford 3491

AP300/18

FORMER troubles disappear with Tufnol

You'll find Tufnol tube makes the best coil formers.
Tufnol is a high-grade electrical insulator. Won't rot or corrode.
Strong and durable wherever you put it to work . . .
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Tufnol coil formers or other components can be
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you to machine in your own workshop.

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312

A HIGH Mu PENTODE
with low hum, noise and microphony

TYPICAL OPERATING CONDITIONS				
Anode Voltage (Va)	250	250	250	250
Screen Voltage (Vg_2)	80	100	160	200
Grid Bias (Vg_1)	1.25	1.7	2.75	3.5
Anode Current (mA)	7.8	7.9	10.5	12.3
Screen Current (mA)	2.45	2.5	3.3	3.85
Mutual Conductance (mA/V)	7.0	7.0	7.45	7.6
Anode AC Resistance (ra) (Megohms)	0.55	0.55	0.4	0.3
Input Capacity (Hot) ($\mu\mu$F)...	20	19.9	19.7	19.5

RATING		
Heater Voltage	V_h	4.0
Heater Current (Amps)	I_h	1.0
Maximum Anode Voltage	V_a	250
Maximum Screen Voltage	Vg_2	250
Mutual Conductance (mA/V)	gm	7.7

Taken at V_a=250; Vg_2=100; Vg_1=1.5

BASE

British 7 pin	Pin No. 5 Heater
Pin No. 1 Metallising	Pin. No. 6 Cathode
Pin No. 2 Anode	Pin No. 7 Screen (g_2)
Pin No. 3 Suppressor Grid (g_3)	Top Cap Control Grid (g_1)
Pin No. 4 Heater	

The AC/SP3 RH is available in two grades. The valves in both grades are characteristically identical, the grading 'A' or 'B' relating only to relative levels of hum, noise and microphony. B Grade valves are suitable for the majority of applications, but for particular applications where the noise level is very important Grade A may be preferred.

Under typical operating conditions with V_a=250v, R_a=150 KΩ, Rg=150 KΩ, Rg_2=500 KΩ, R_k=1 KΩ, with the heater fed from a centre-tapped A.C. supply the equivalent hum voltage at the grid of an average grade A valve is approximately 5μV, whilst the combined noise (excluding hum generated by the valve and grid resistances, using a high quality A.F. amplifier) is not greater than 8μV.

The following table compares the noise, hum and microphony from the two grades of valve.

HUM	NOISE
'A' × 5.6 down on 'B'	'A' × 2 down on 'B'

MICROPHONY
'A' × 8 down on 'B'

SV3

THE EDISWAN MAZDA AC/SP3 RH is an indirectly heated Pentode with a special heater construction designed to reduce hum due to A.C. fields within the valve.

Provided precautions are taken to minimise hum due to external wiring, the AC/SP3 RH may be used in the early stages of amplifiers where the reduction of hum, noise and microphony is of primary importance.

Full technical information on request.

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MAZDA
VALVES & CATHODE RAY TUBES

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155 Charing Cross Road, London, W.C.2
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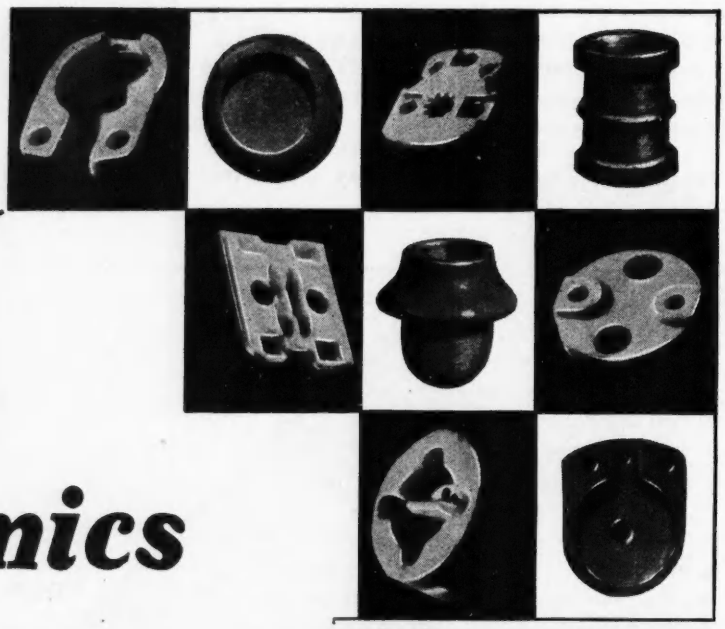

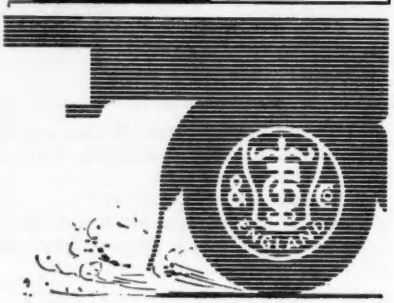

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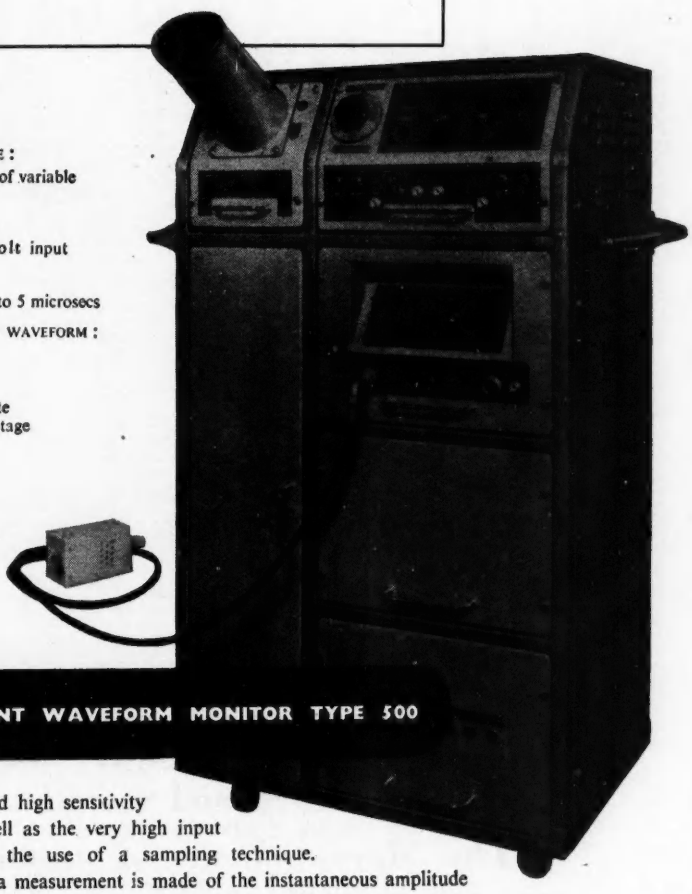
A NEW TECHNIQUE IN HIGH SPEED WAVEFORM MONITORING



BANDWIDTH :
10 kc/s to 300 mc/s

INPUT IMPEDANCE OF EACH PROBE :
Approx. 1 pf (input element of variable capacity divider)

MAXIMUM SENSITIVITY :
Full Scale Deflection for 1 Volt input

TIME SCALE :
Variable from .05 microsecs to 5 microsecs

RECURRENCE RATE OF MONITORED WAVEFORM :
100 c/s to 10 kc/s

CALIBRATION :
Provision is made for accurate measurement of time and voltage scales of a waveform

PREVENTION OF JITTER :
A circuit is incorporated for providing a stable display when a monitored waveform is jittering with respect to its driving pulse.

HIGH SPEED RECURRENT WAVEFORM MONITOR TYPE 500

The wide bandwidth and high sensitivity of the instrument as well as the very high input impedance result from the use of a sampling technique. During each recurrence a measurement is made of the instantaneous amplitude of one point in the waveform. This measurement is amplified and applied to the cathode ray tube as one co-ordinate of a graph of the waveform. During subsequent recurrences, instantaneous measurements are made of different points, resulting, after about 100 recurrences, in a complete graph.

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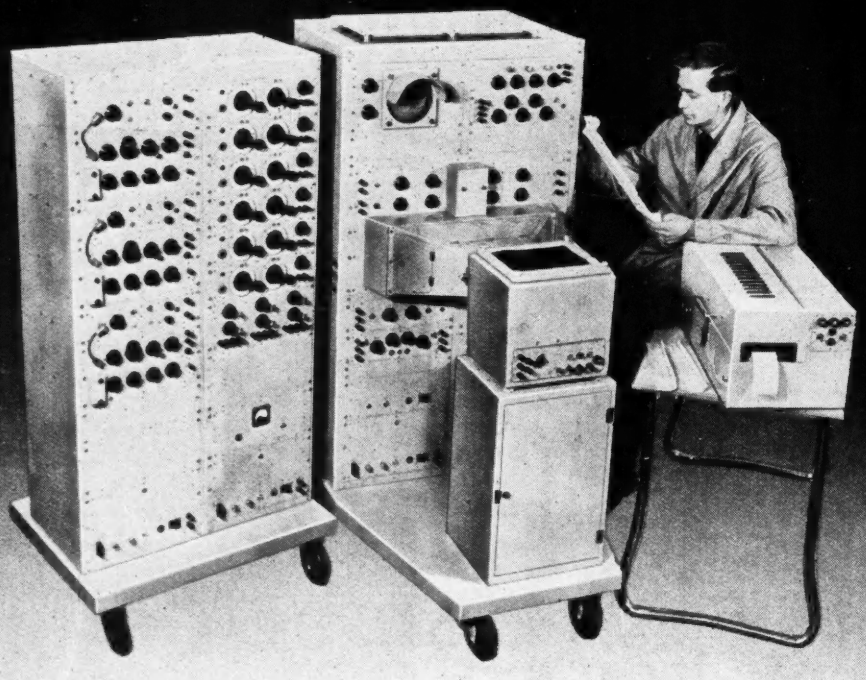

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The development of modern ships, aircraft, engines, machines and armaments of all kinds already owe much to such MINIRACK Oscillographs.

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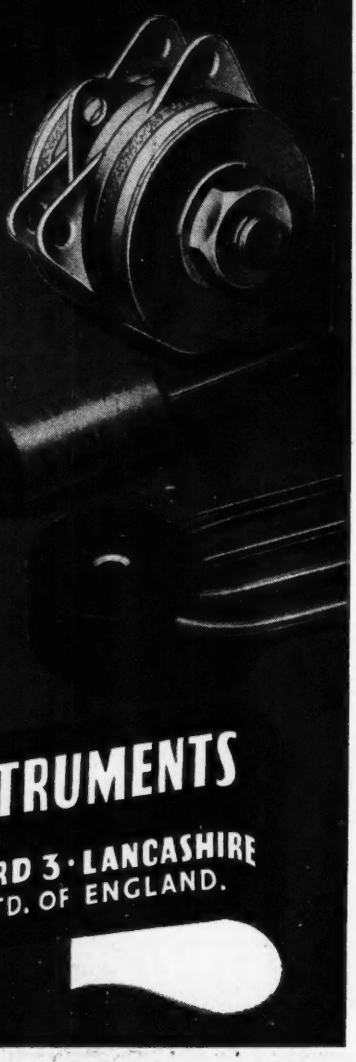

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Laboratory Instruments

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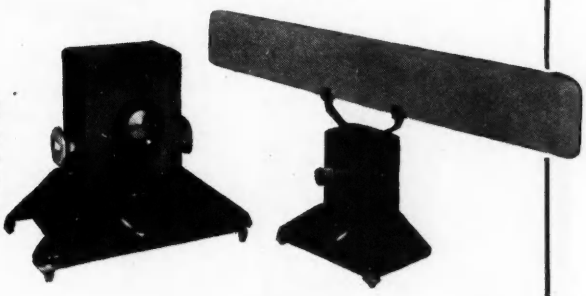

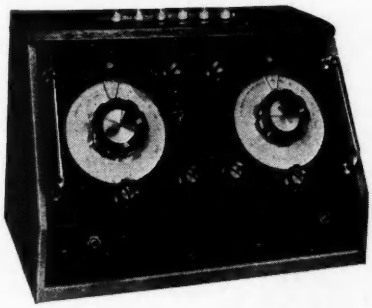

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A wide range bridge for the measurement of resistance, capacitance and inductance between 15 Kc/s and 5 Mc/s. It will measure complex impedances balanced and unbalanced and between any pair of terminals in a three terminal network.

Video Oscillator — Type 0.22B

A portable instrument covering the range 10 Kc/s to 10 Mc/s with an output of + 10 dbs to — 50 dbs on 1 volt p. to p. amplitude stabilised to 0·5 dbs over its full frequency range. It includes a 50 cps. square wave output and facilities for direct reading of the modulus of the load impedance.

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AF HF and VHF Bridges Signal Sources Component Test Gear
Microwave Apparatus Special Purpose Equipment

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Ref.	Type	Loading	Max. Volts	Range	Dimensions
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T	¼ watt	¼ watt	250	10 ohms to 10 megohms	⅜" × ⅛"
R	½ watt	1 watt	500		⅝" × ¼"
Tolerance available ± 20%, 10%, 5%					
HIGH STABILITY RESISTORS					
HS3	½ watt	½ watt	750	1 ohm to 500 megohms	1.1" × 0.1"
Tolerance available ±5%, 2%, 1%					
WIREWOUND RESISTORS 5 ohms to 100K ohms — 5 - 10 watts					
'CERAMICAPS' Tubulars 3 - 470 pf 500 - 5000 pf Tolerances ±2%, 10% Hi-K					

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★ **Values separately carded**

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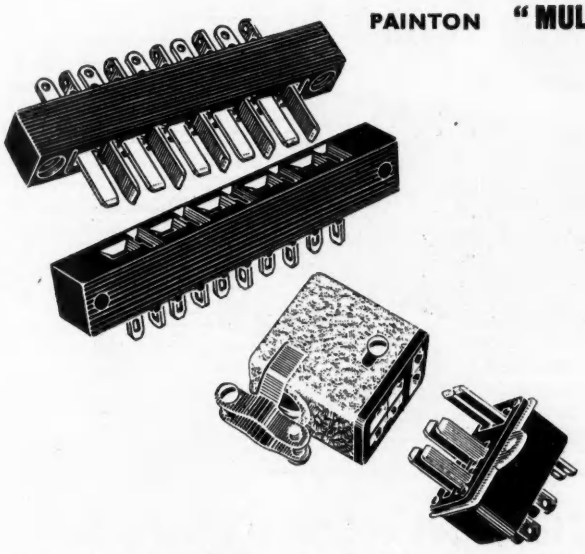

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2 pole 4 pole 6 pole
8 pole 12 pole 18 pole
24 pole 33 pole
and 10-in-line unitor.

Voltage Rating: 500 volts. D.C. or A.C. Peak.

Current Carrying Capacity : 5 amps. D.C. or A.C. (R.M.S.) per contact.

Average Contact Resistance : Less than 0.005 ohm.

Single-piece moulding ensures satisfactory operation under severe tropical and climatic conditions.

SERVICES RANGE

6 pole 12 pole
18 pole 24 pole

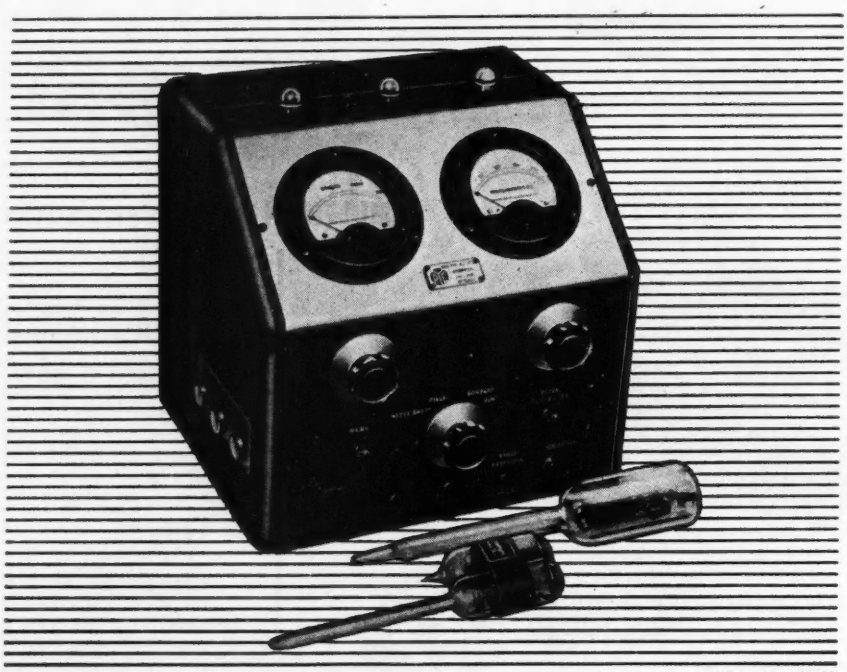
Voltage Rating, Current Carrying Capacity and Average Contact Resistance are the same as for the Commercial Range.

Two-piece die-cast cover enables soldered joints and cable-clamping arrangements to be inspected easily.

Single-piece moulding ensures tropical and climatic performance in accordance with RCS.321 standards.

PAINTON

Northampton England.



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PIRANI AND IONISATION GAUGE

FOR RAPID, PRECISE VACUUM MEASUREMENTS IN RESEARCH & INDUSTRY

The "CATHODEON" COMBINED PIRANI AND IONISATION GAUGE is a compact, self-contained, mains-operated unit for measuring pressure over the very wide range of 1 mm. to 10^{-6} mm., or less of mercury. A Pirani gauge is used over the range of 1 mm. to 10^{-3} mm. Below 10^{-3} mm. a selector switch brings in an ionisation gauge indicating down to 10^{-6} mm. or less. Occluded gases in this gauge may be removed by a built-in "Bombard" feature. Indicator lamps show whether the instrument is set to "Pirani," "Ionisation," or "Bombard." Complete with Pirani and Ionisation gauge heads which are normally supplied in hard or soft glass of 12 mm. bore, but are available in special glasses, bores or connectors to suit customers' requirements. Descriptive leaflet available on request.

SPECIAL FEATURES

Robust Probes included. Simplified Controls. Range extension readily available.

STANDARD EQUIPMENT IN MANY LEADING LABORATORIES

SCIENTIFIC PYE INSTRUMENTS

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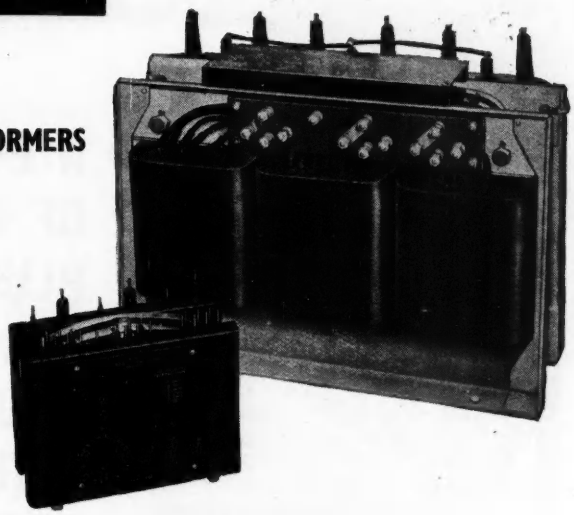
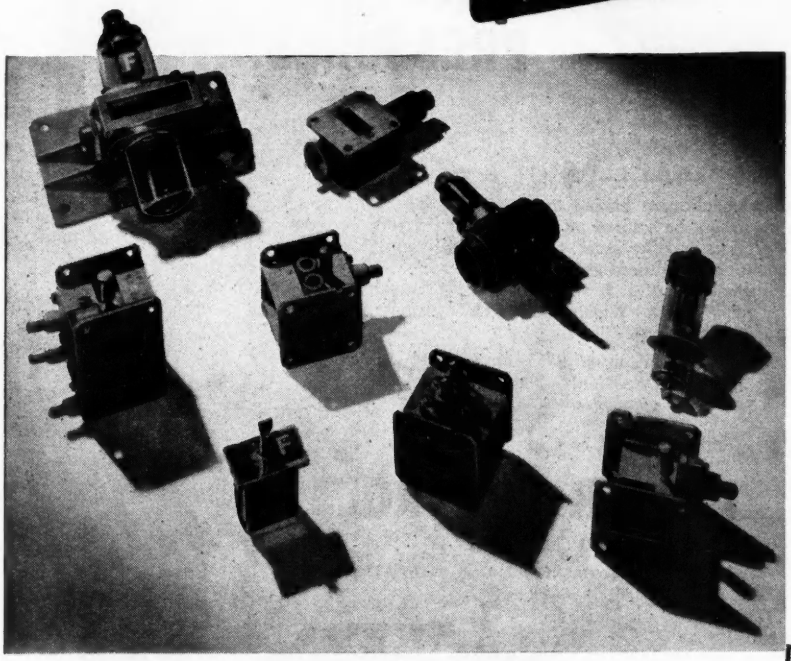
WG61

FERRANTI

THREE PHASE RESIN CAST TRANSFORMERS

The 'Pentland' Series of Resin Cast Components has been extended to include Three-Phase Transformers with ratings up to approximately 4kVA at 50 c.p.s. Correspondingly greater ratings are available at the higher frequencies.





T.R. and A.T.R. CELLS FOR RADAR EQUIPMENTS

The Ferranti ranges of T.R. and A.T.R. Cells cover the 3 cm., 10 cm., and 30 cm. bands. Tunable and Broad Band types are available and a number of American Equivalents are manufactured.

Enquiries to:

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Ferranti Ltd.
Ferry Road, Edinburgh 5

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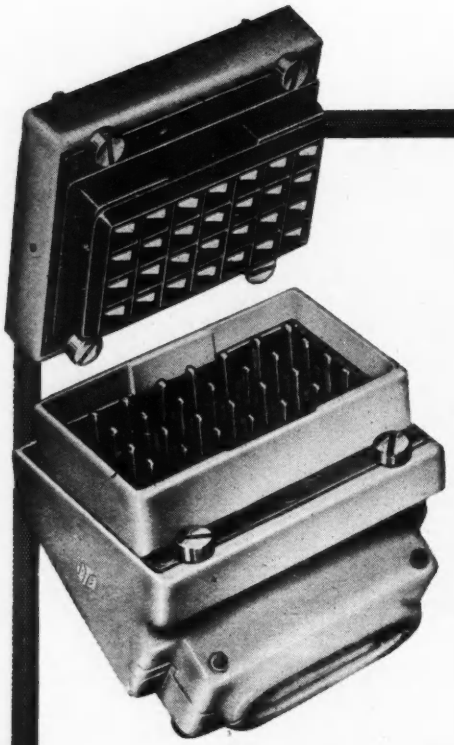
FERRANTI LTD., CREWE TOLL, FERRY ROAD, EDINBURGH 5

London Office : KERN HOUSE, 36 KINGSWAY, W.C.2

ES/TIS



A PROVED RANGE OF MULTI-WAY PLUGS AND SOCKETS WITH UNUSUALLY LOW INSERTION PRESSURES.

Multi-way Plugs and Sockets with years of experience and application behind them. When specifying these high quality components you will be assured of less insertion pressure per contact than any comparable product can offer, great versatility, and suitability for humid conditions. For rack mounting applications greater latitude in matching up eases the designers problem, and the range of 4, 8, 12, 20 and 28 way units will be found to cover almost every requirement. Widely used by such manufacturers of high quality equipment as:

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The English Electric Co. Ltd.

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LIMITED

EXNING RD., NEWMARKET PHONE: NEWMARKET 3181

R/H

GYRO CALIBRATION TABLE WITH PRECISION SPEED CONTROL

Designed to facilitate the testing and calibration of Gyro mechanisms and similar equipments, the GI Calibration Table provides an infinitely variable speed range from 0 to 80 RADS/SEC.

Precision control is such that table speeds can be set and held to within 0.2% throughout the range and in either direction of rotation.

Both air and electrically driven gyros can be tested by means of 12 independent electrical connections and an air supply to the rotating table. Other facilities include a built in stroboscopic speed indicator and an arresting unit for the observation of damping characteristics.

The entire drive from motor to table is by positive gearing through a four speed gear box. Electro-mechanical interlocks are provided to prevent damage by mishandling.

The power pack and amplifier are combined in a self-contained unit and operate from 230v. 50 ~ supply. Stability is ensured by a drift compensated velodyne control system.

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This and other instruments of control and measurement will be on view at the British Instrument Exhibition on our Stand No. 3 F.

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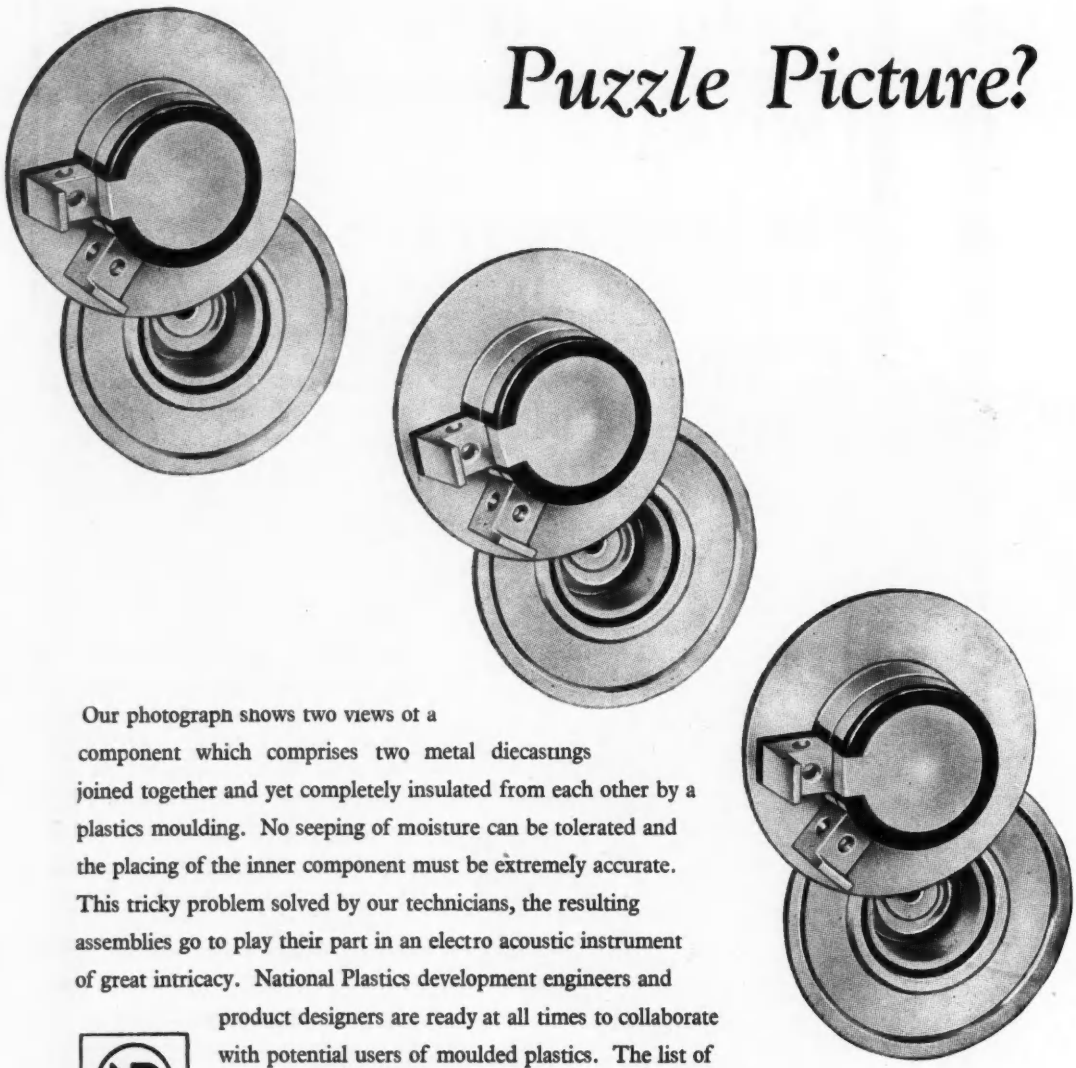
Puzzle Picture?



Our photograph shows two views of a component which comprises two metal diecastings joined together and yet completely insulated from each other by a plastics moulding. No seeping of moisture can be tolerated and the placing of the inner component must be extremely accurate. This tricky problem solved by our technicians, the resulting assemblies go to play their part in an electro acoustic instrument of great intricacy. National Plastics development engineers and product designers are ready at all times to collaborate with potential users of moulded plastics. The list of new applications developed and put into production in recent months is most impressive.

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NATIONAL PLASTICS (SALES) LTD.
Sales Organisation for
BRITISH MOULDED PLASTICS LTD.

Avenue Works, Walthamstow Avenue, London, E.4
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20 Mc/s FREQUENCY MONITOR

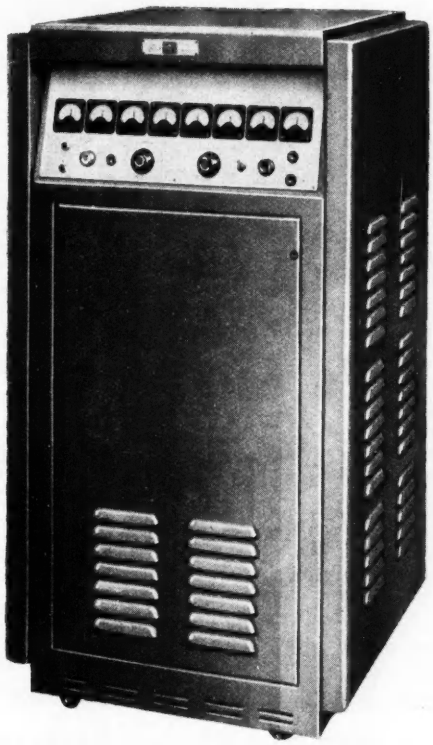
The Automatic Frequency Monitor (20 Mc/s) is but one of a series of high grade monitors now in course of manufacture for the accurate measurement of frequency.

Employing hard valve techniques throughout, it will measure any frequency in the range 10 c/s to 20 Mc/s to an accuracy within ± 1 part in 10^6.

The result, in decimal notation, is presented on eight panel mounted meters each scaled from 0 to 9 and the unknown frequency is automatically remeasured every few seconds.

This new equipment presents a considerable advance in frequency measuring techniques and apart from normal laboratory applications, is ideally suited for incorporation in production testing routines.

Full technical information on this and other frequency measuring equipment is available on request.



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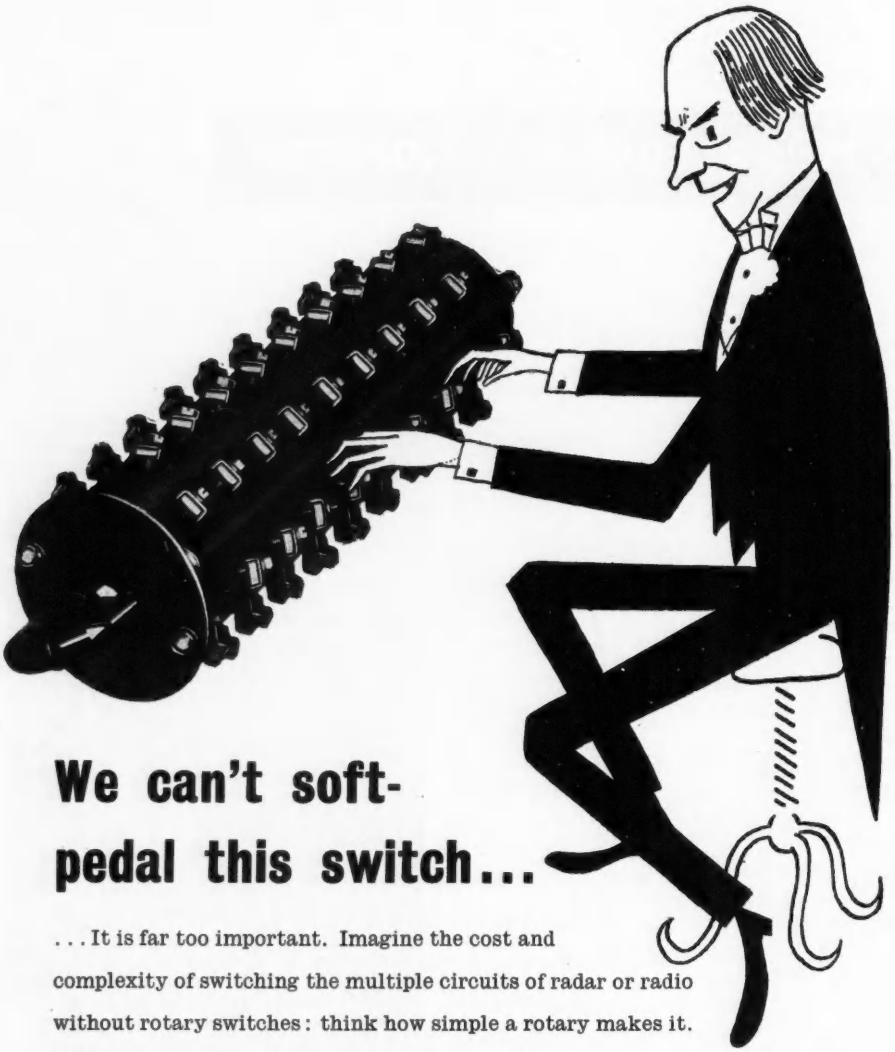

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. . . It is far too important. Imagine the cost and complexity of switching the multiple circuits of radar or radio without rotary switches: think how simple a rotary makes it. Go on to ask the obvious question: Why not the same simplification of industrial power switching? Why not indeed! Austinlite Rotaries are designed for that very purpose. They switch more compactly, more cheaply, more simply than conventional switchgear . . . and every switch is built for its job. Tell us what the circuits are: we will supply an Austinlite — no matter how special — to switch them. The switches are described in a technical brochure 'Simplified Switching' — copies are available on request.

Rotary switching is 'Simplified Switching'

ask *Austinlite* about it

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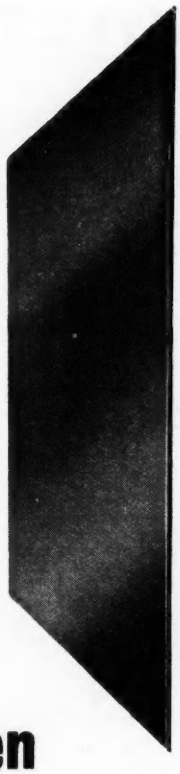
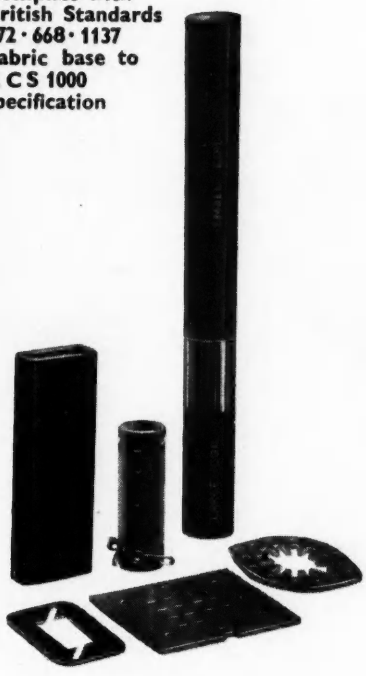
(A subsidiary of Stone-Chance Ltd., the makers of Sumo Pumps and Stone-Chance Lighthouses.





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Wherever an efficient combination of mechanical strength and sound insulating properties is required, 'Pirtoid' provides the modern answer.

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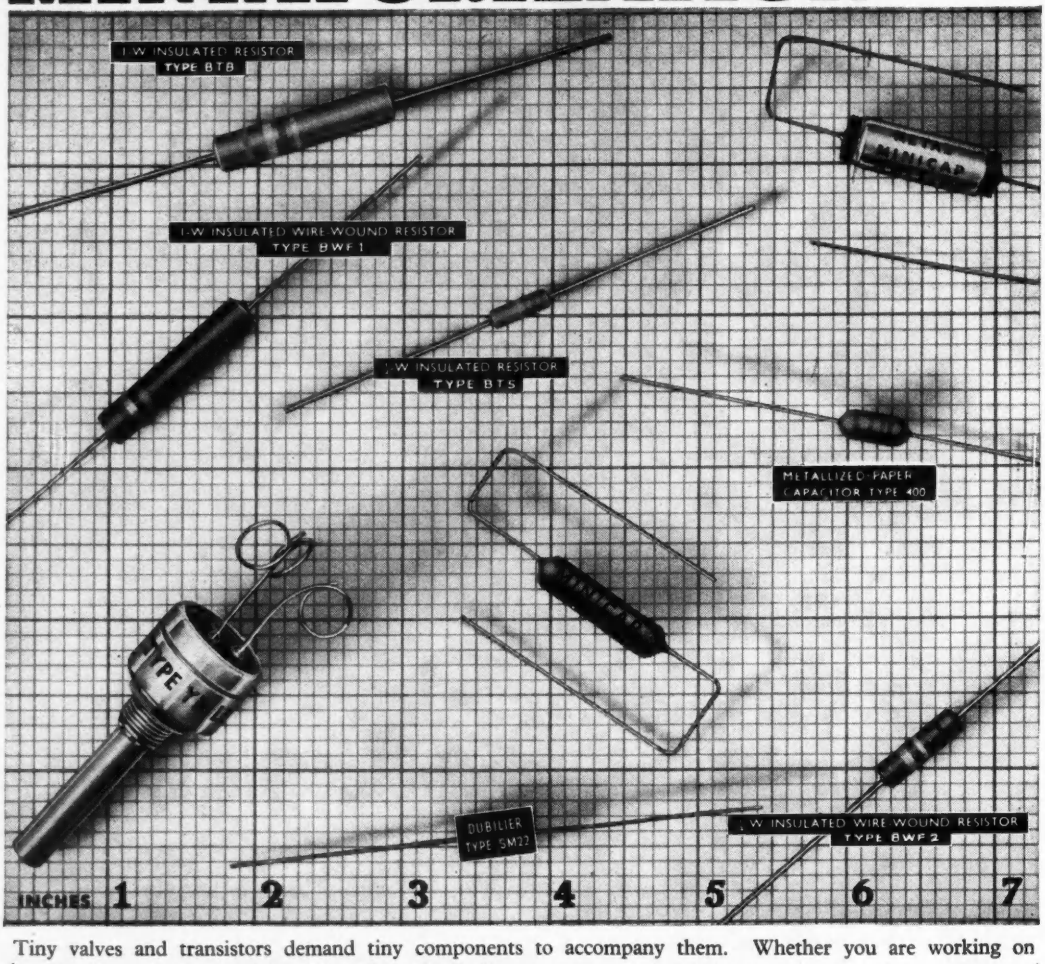
MINIATURIZATION



Tiny valves and transistors demand tiny components to accompany them. Whether you are working on television for Bands III and IV, Band II Radio, computors, industrial electronics or test gear, these components will undoubtedly interest you. Deserving of special mention are the tiny BTS type ½-W. resistor measuring only $\frac{3}{8}'' \times \frac{1}{8}''$ and the type 400 metallised paper capacitor in its melt-proof cover. For those of you concerned with tropicalization, BTS, BTB and BWF2 resistors, YN-potentiometers and metal 'minicap' capacitors will be of special interest. To those of you engaged on Government contracts we should like to mention that the metal 'minicap' capacitor and the type BTS and BTB resistors are type-approved. Send for samples and catalogues by dropping us a line on your company's letter-heading.

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DUBILIER CONDENSER CO. (1925) LTD., DUCON WORKS, VICTORIA ROAD, NORTH ACTON, LONDON, W.3
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DN. 125A

Connollys have never been checkmated or even checked in their steady progress as one of the world's leading manufacturers of winding wire.

Checks however, do take place—stringent quality checks—enabling Connollys to build up a fine reputation amongst discriminating users.

Their Conymel wire (vinyl acetal coated to B.S.S. 1844) has a world wide reputation as being the best of its type and Connollys are one of the largest manufacturers of this wire in the British Empire.

CONNOLLYS *Winding Wires*

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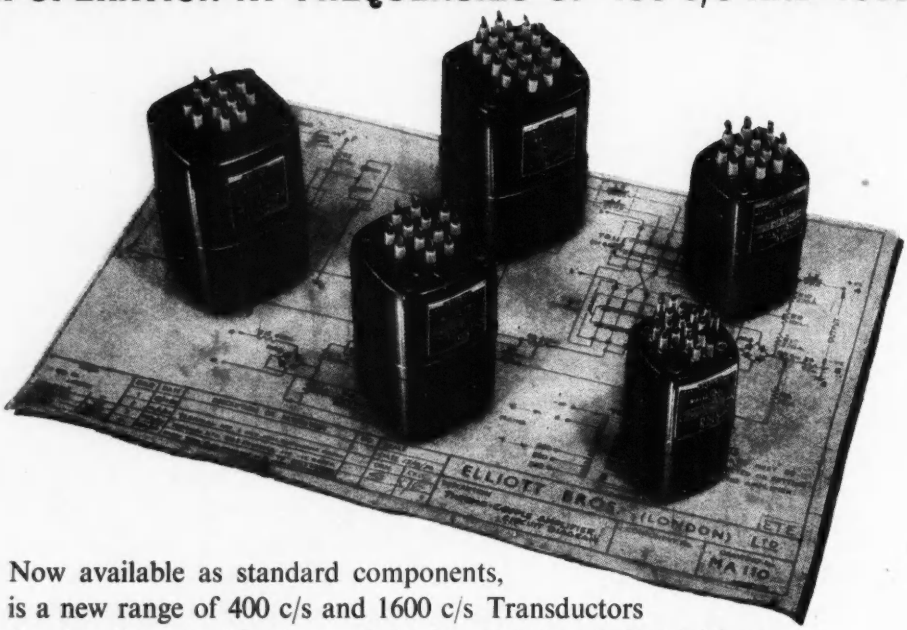
ELLIOTT

Standard Transductors

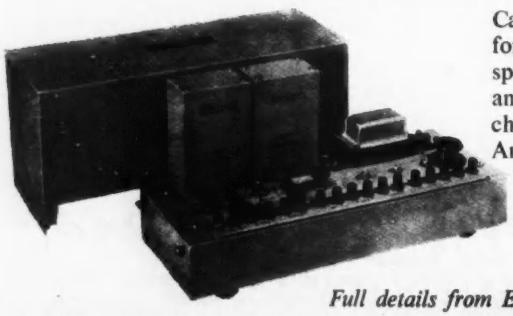
FOR OPERATION AT FREQUENCIES OF 400 c/s AND 1600 c/s



Now available as standard components, is a new range of 400 c/s and 1600 c/s Transductors developed to specifications of the Royal Aircraft Establishment.

- Hermetic sealing.
- Push-pull input transductor units.
- Output transductors rated up to 80 watts.
- Decreased time constants.
- Reduced dimensions and weights.
- Exceptional life without maintenance.
- Extreme ruggedness.
- Multiple isolated inputs.
- Summation of inputs.
- Stable D.C. amplification.

DEMONSTRATION MAGNETIC AMPLIFIER



Capable of being set up rapidly in various circuit forms, this flexible general purpose instrument is specially designed to enable electronic engineers and students to gain practical experience of the characteristics and applications of Magnetic Amplifiers. For use in Research Establishments, Development Laboratories, Technical Schools and Colleges. Price £42. 15s. 0d. (50 c/s model only).

Full details from Elliottronics Division

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EPSYLON MULTITRACK TAPE RECORDING SYSTEM

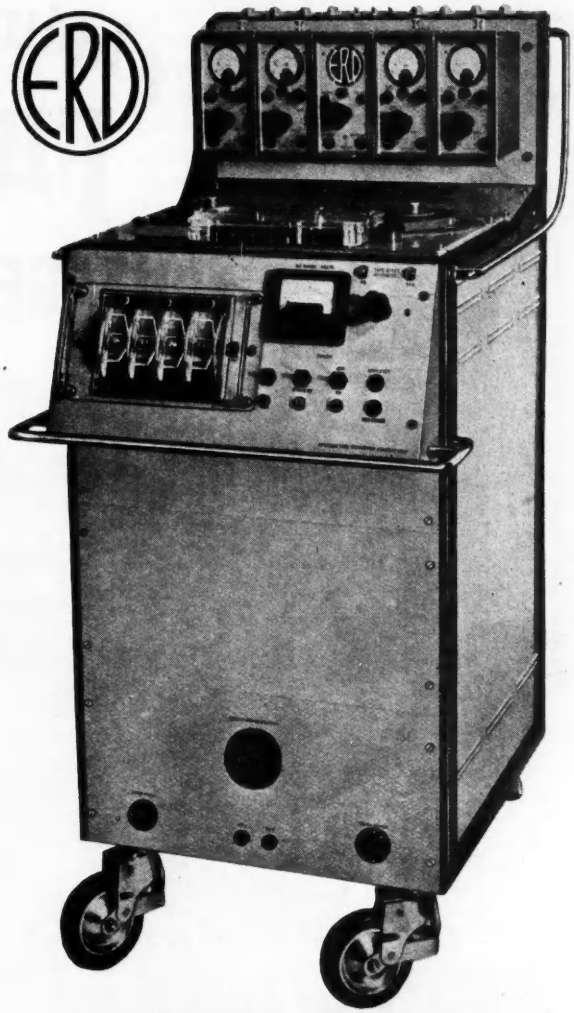
Four tracks recorded in phase per $\frac{1}{4}$" Tape width up to 16 tracks on one inch.

Tape speeds from 0.75 ins./sec. to 100 ins./sec. and above.

Modulated and direct systems to record from D.C. to 120 Kc/s.

Remote and Automatic control.

The console equipment illustrated is a 4-channel direct recording system, having speeds of 37.5 and 75 ins./sec.



EPSYLON MULTITRACK TAPE ANALYSER

This instrument has been developed to facilitate the examination of recorded tapes. Any small portion of a stationary tape is repeatedly scanned by a rotating head assembly, producing a recurrent oscillographic display for observation or photographic recording.

Supplied by :—

EPSYLON SOUND ACCESSORIES LTD.

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On Top of every Industrial need...

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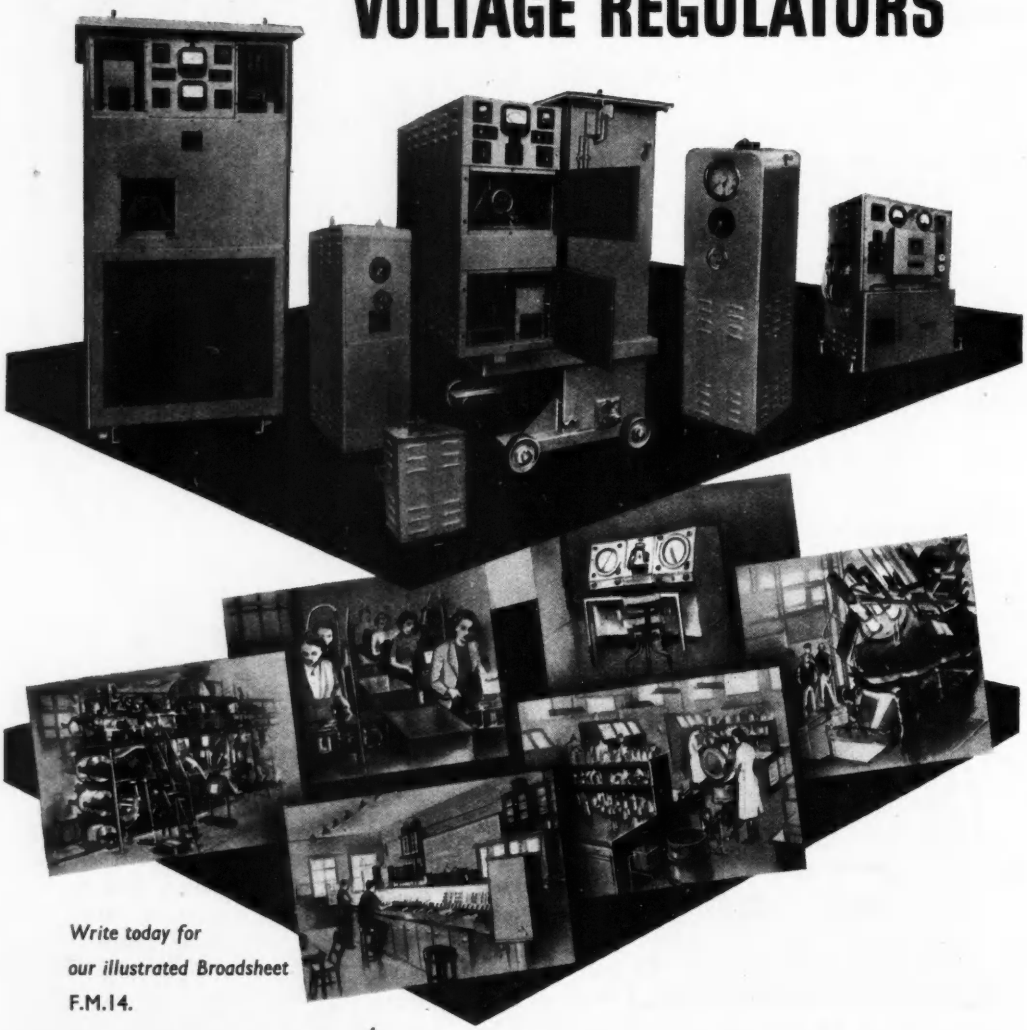
VOLTAGE REGULATORS



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Specialists in Dependable Power Regulating Equipment

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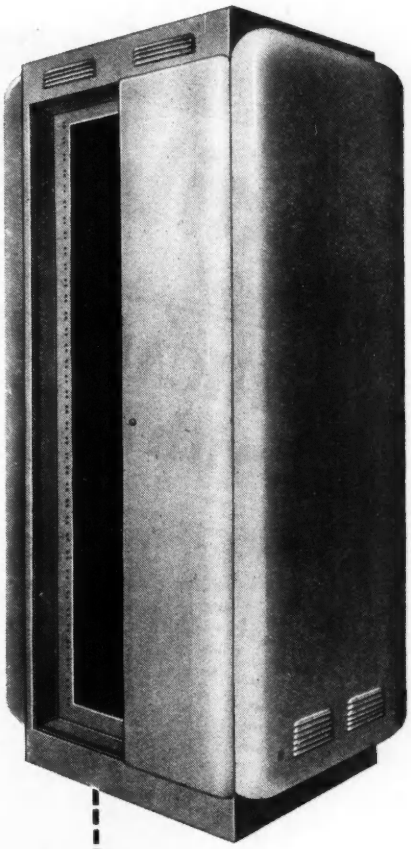
A 'LANCASHIRE DYNAMO HOLDINGS' COMPANY

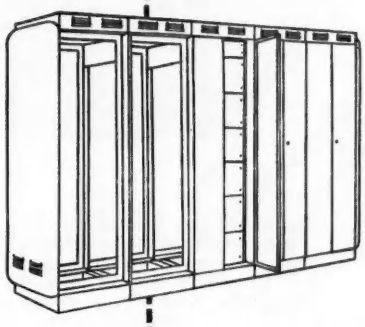
VR/6

6′ 0″ Enclosed Standard Cabinets



These superior enclosed Cabinets are available at an economical price, yet still maintain to perfection, the excellent standard of material, craftsmanship and finish that has become a feature of the H. & H. range. These Cabinets may be used singly or, as shown below, in Unit Formation—in which case the protruding side panels are removed and the units bolted together.

A Catalogue of H. & H. Cabinets, Racks and Cases, giving details of the full range is available upon request.



Unit Formation

Hassett & Harper Ltd

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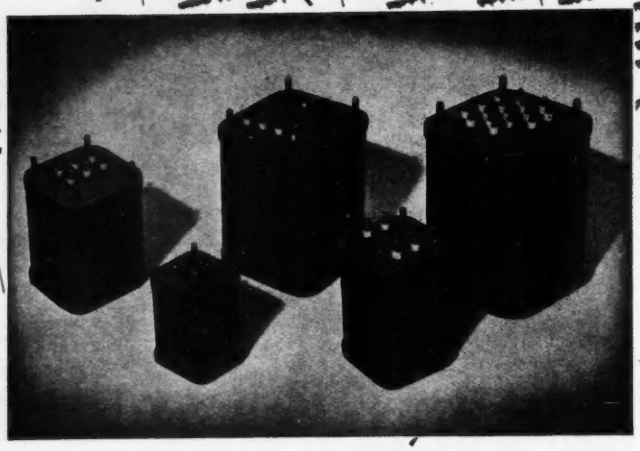
CONTRACTORS TO GOVERNMENT DEPARTMENTS

TRANSFORMER PROBLEMS WE HAVE SOLVED...

AMERICAN SPECIFICATION MIL/T27 met with BRITISH MATERIALS



Implementing the policies of N.A.T.O. has brought its own problems not the least of which are the varying electrical properties of the actual raw materials selected for electronic and radio equipment and components. The news that Gresham Transformers have completely and successfully met the requirements of American Specification MIL/T27 is yet another achievement which goes to prove that—

—To Every Transformer Problem
There is a GRESHAM *Answer*

HANWORTH **GRESHAM** MIDDLESEX
TRANSFORMERS LTD

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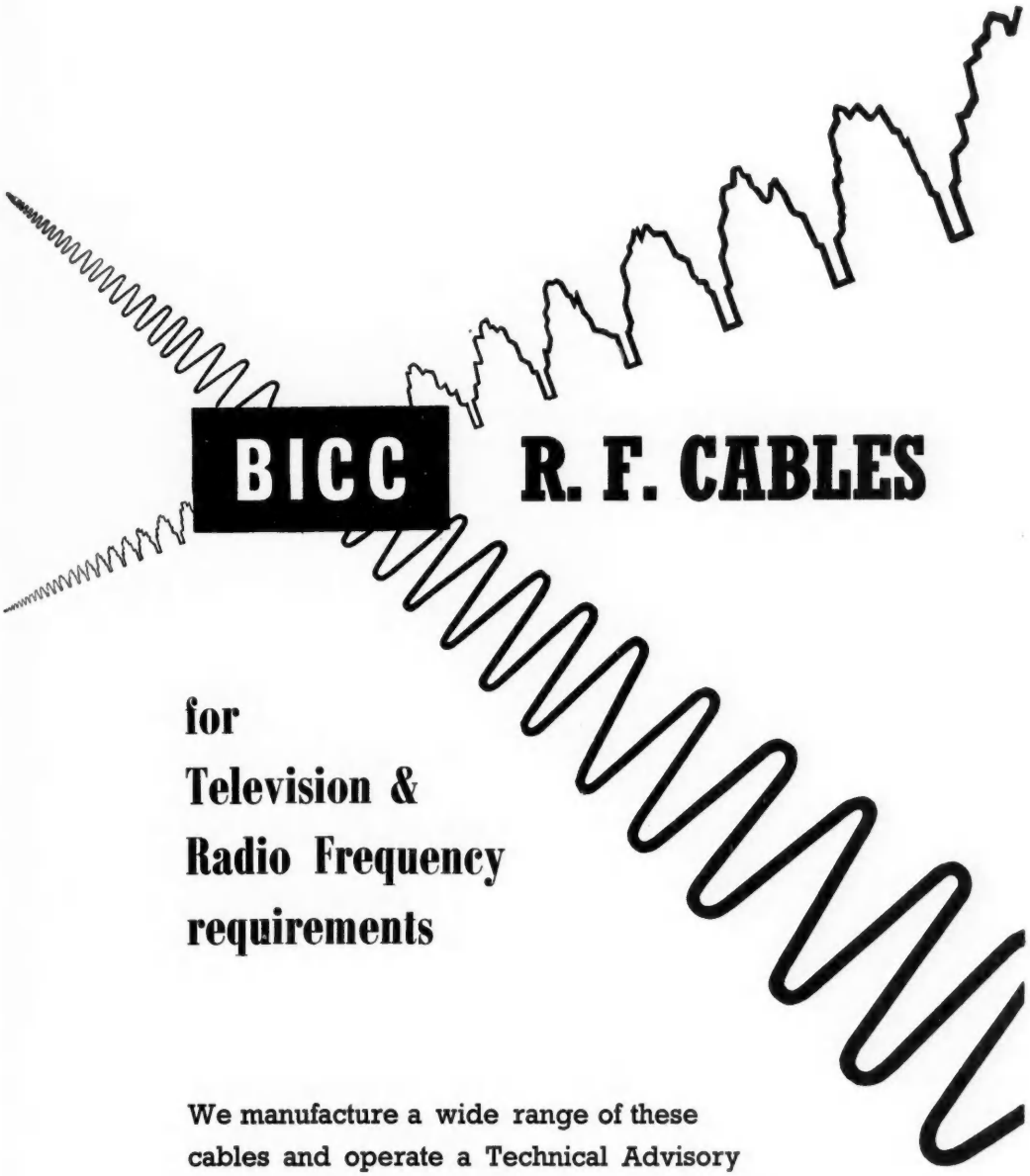

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Television &
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We manufacture a wide range of these cables and operate a Technical Advisory Service which is always at your disposal

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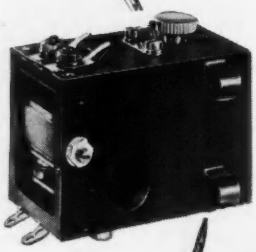
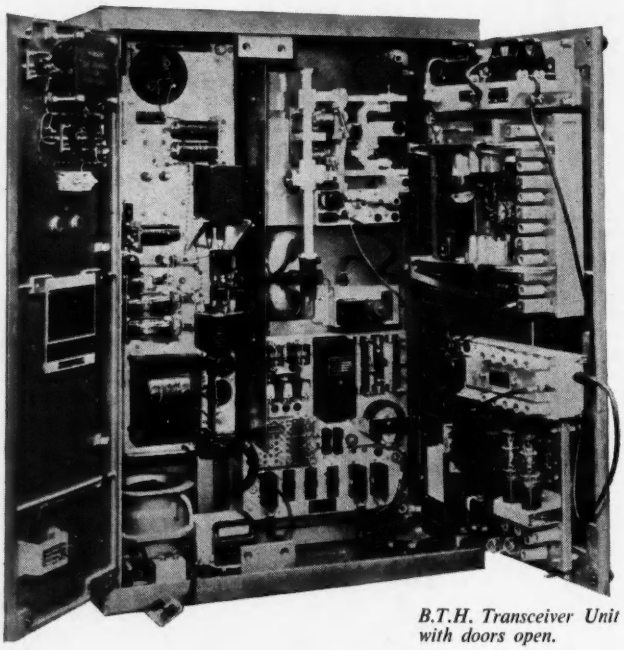
PROGRESS IN CONTROL

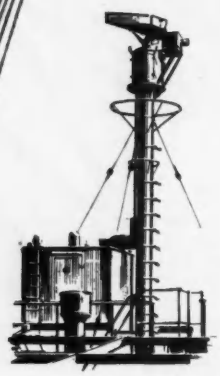
SUNVIC
TIME DELAY
SWITCHES



BRITISH INSTRUMENT INDUSTRIES EXHIBITION
•
STAND 17
BLOCK C



B.T.H. Transceiver Unit with doors open.



The use of Sunvic time delays for vital applications in aircraft is an example of their undoubted reliability and consistency. They provide delays from 3 seconds to 6 minutes unaffected by variations in ambient temperature. They are used by all the leading manufacturers of radar equipment for circuit protection and have a variety of other applications, including filament protection in electronic equipment and sequence switching.

Another example of the important part played by—

EQUIPMENT BY SUNVIC

SUNVIC CONTROLS LTD. (Special Products Divn.), No. 1 Factory, Eastern Industrial Estate, Harlow, Essex. 'Phone: Harlow 24231/5

Manufacturers of Pneumatic and Electrical Instruments for detection, measurement, control and recording of Temperature, Flow, Liquid Level, Specific Gravity and Pressure, in Science and Industry. Vacuum Pumping and Measuring Equipment, etc.

Member of the A.E.I. Group of Companies

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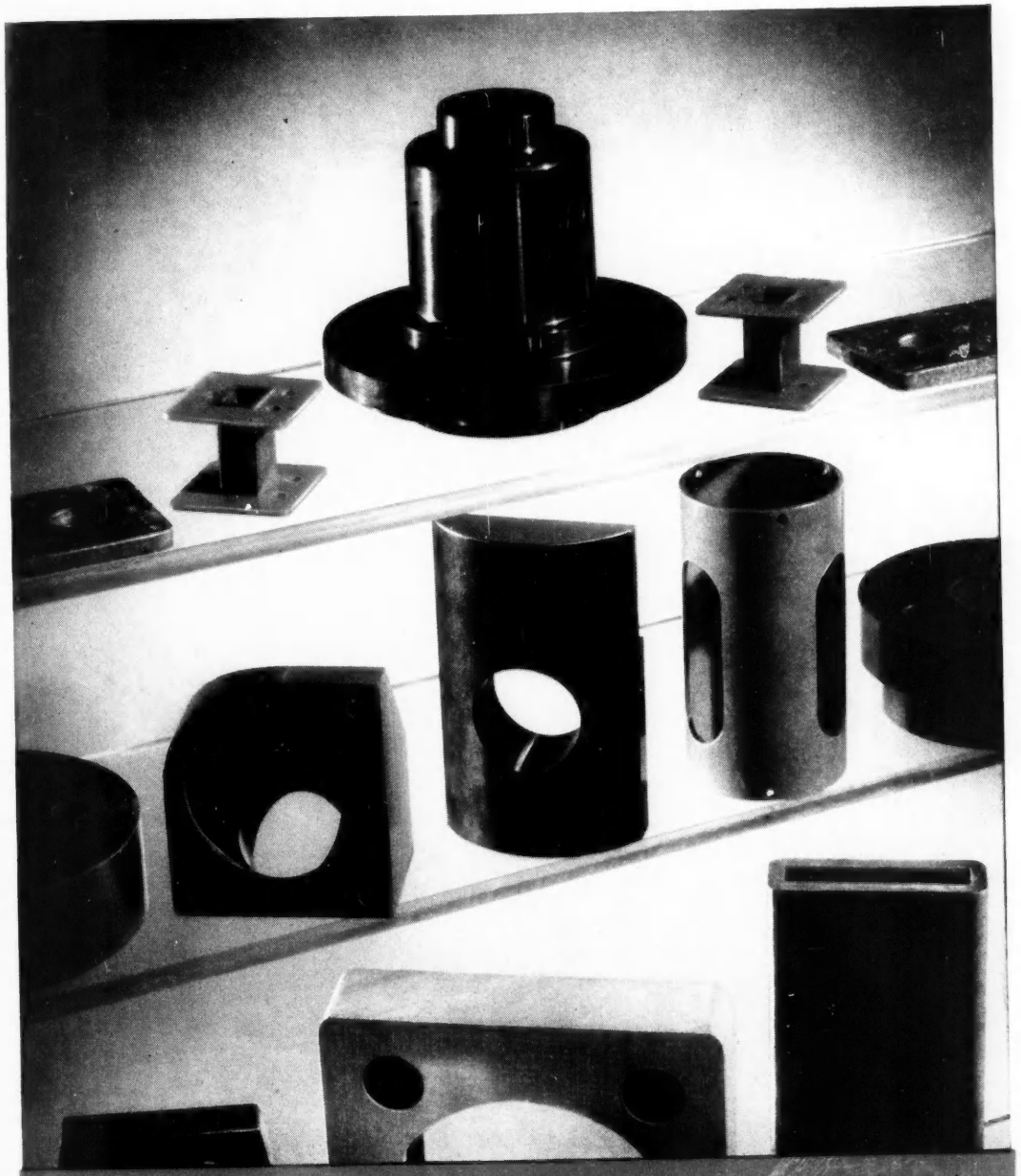

With our extensive facilities and long experience, we can undertake the most intricate machining operations upon electrical insulating materials. Here are some examples of vulcanised fibre, Paxolin and Panilax.

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THE MICANITE & INSULATORS CO. LTD.

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BRANCH OFFICES AT BIRMINGHAM, CARDIFF, GLASGOW, MANCHESTER AND NEWCASTLE UPON TYNE AND REPRESENTATIVES IN MOST COUNTRIES THROUGHOUT THE WORLD. IN CANADA, MICANITE CANADA LIMITED.

Manufacturers of MICANITE (Built-up Mica Insulation). Fabricated and processed MICA. PAXOLIN Laminated Materials. PANILAX Laminated Materials and Mouldings. EMPIRE Varnished Insulating Cloths and Tapes. HIGH VOLTAGE BUSHINGS AND TERMINALS. Distributors of Micaflex-Duratube Sleevings, Micaflex-Duraisleeve (Plastics-covered flexible metal conduit). DURAJOINT (Patented Expansion Jointing for Concrete Structures) and Kenotel Injection Mouldings (in most thermoplastics including P.V.C.).

EPOXY RESINS MEAN 'ARALDITE'!—NOW AVAILABLE AT LOWER COST

Araldite

EPOXY RESINS

These versatile resins have a remarkable range of characteristics and uses. They combine excellent adhesion with insignificant shrinkage on setting, flexibility with toughness, outstanding electrical properties with resistance to chemicals and exposure.

They are used

- *for bonding metals and ceramics*
- *for potting and sealing electrical components*
- *for producing glass cloth laminates*
- *for producing jigs, fixtures, patterns and tools*
- *as fillers for sheet metal work*
- *as protective coatings for metal surfaces*

Full details will be sent on request. 'Araldite' regd. trade mark.

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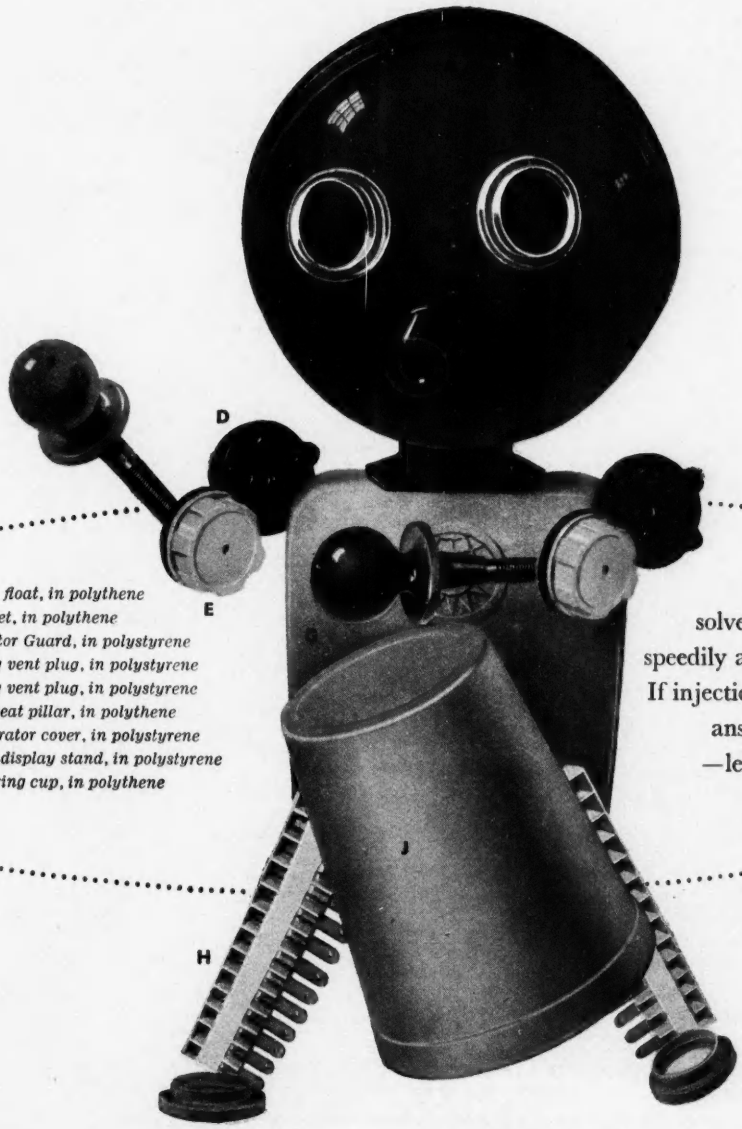
Duxford, Cambridge.
Telephone : Sawston 187. A Ciba Company.

He's a big noise . . .

In fact, every bit of him is important. He's composed entirely of different injection mouldings—all of them produced for well-known manufacturers by the lively lads at Lorival.



A *Cistern float, in polythene*
B *Grommet, in polythene*
C *Separator Guard, in polystyrene*
D *Battery vent plug, in polystyrene*
E *Battery vent plug, in polystyrene*
F *Toilet seat pillar, in polythene*
G *Refrigerator cover, in polystyrene*
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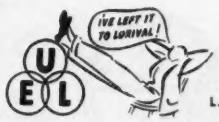

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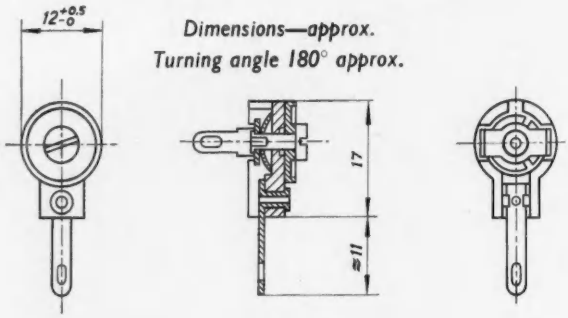
VARIABLE CAPACITORS

Ceramic Disc Trimmers "Bow" Type

Diameter of rotor 12 mm.



Dimensions—approx.
Turning angle 180° approx.

Rated voltage	250 V—/175 V~				
Testing voltage	750 V—				
Material of rotor	**D6**	**D20**	**D40**	**D50**	**D90**
Abbreviated designation inside width of bow 10 mm. inside width of bow 12 mm.	12 Triko 10 B . . . 12 Triko 12 B . . .				
Regulating capacitance $C_{min.}/C_{max.}$ in pF	2/6	2/8 2/10 3/15	4/20 6/30	3/15 4/20 6/30	3/15 4/20 6/30 10/45 15/45
Tolerances of capacitance $C_{min.}$ $C_{max.}$		+10% −10%+50%			+10% −10%+70%
Loss factor in 10^{-3} for $C_{max.}$ at 1 Mc/s and tgd +20°C	<2	<2	<2	<2	<2
Permittivity of rotor at 1 Mc/s and +20°C ε	≈6	≈20	≈40	≈50	≈90
TC_C in 10^{-6} at 1 Mc/s of rotor +20°C . . . +85°C TK_C	+120 . . . +160	−30 . . . +90	−40 . . . −150	−350 . . . −600	−650 . . . −850
Reactive current A	0,3				
Insulation resistance $R_{is.}$	10^{10} . . . 10^{12} Ω				
Admissible dissipation mW	70				

Example of Ordering : Disc Trimmer " Bow " type 15/45 pF with rotor in D90 and inside width of the bow 10 mm.=12 Triko 10 B 15/45 D90.

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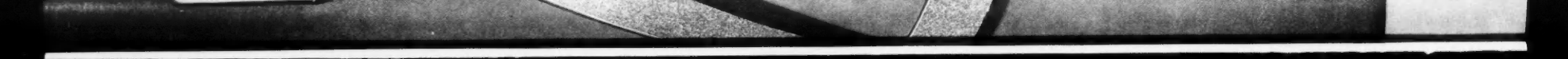

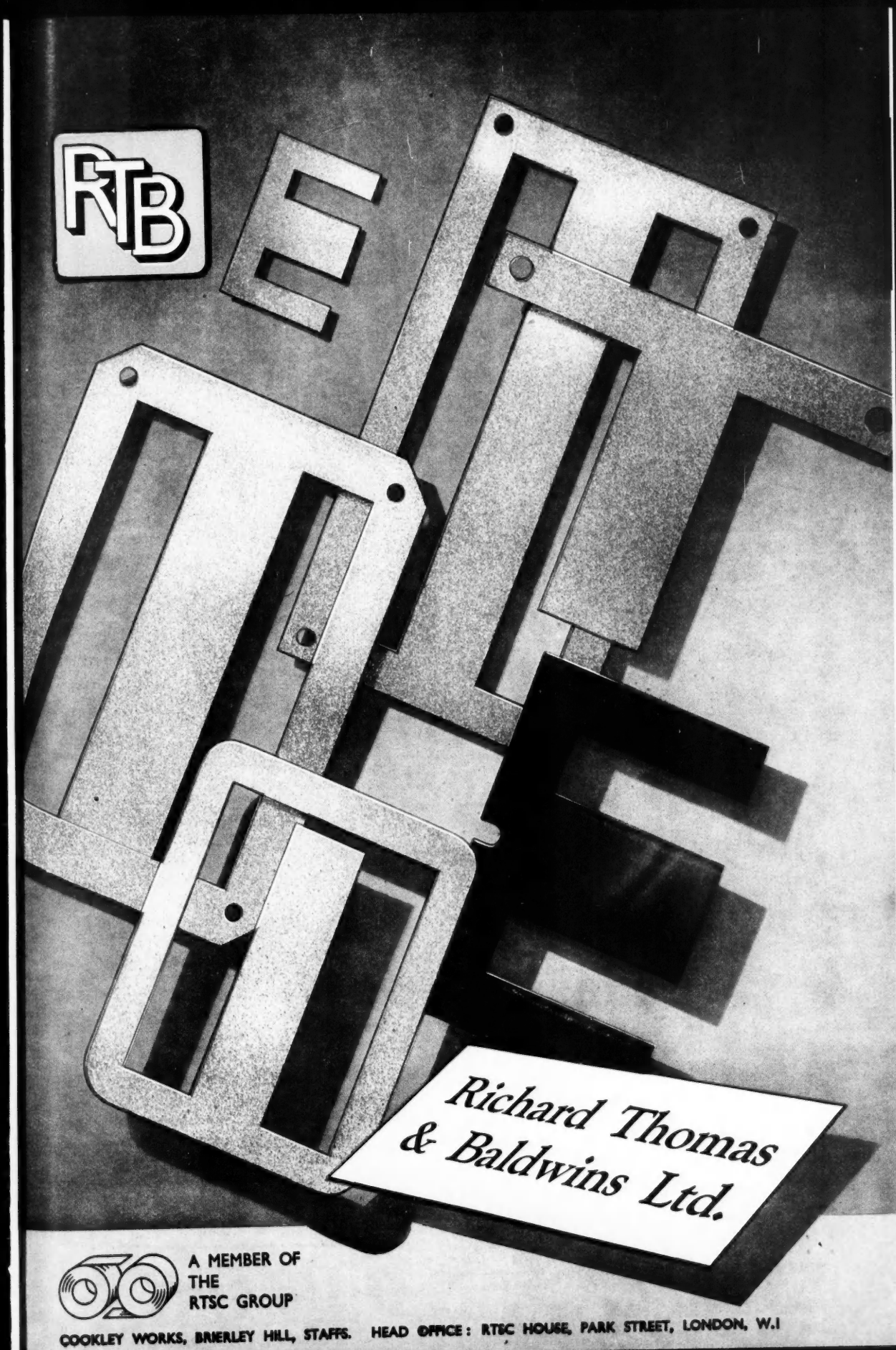

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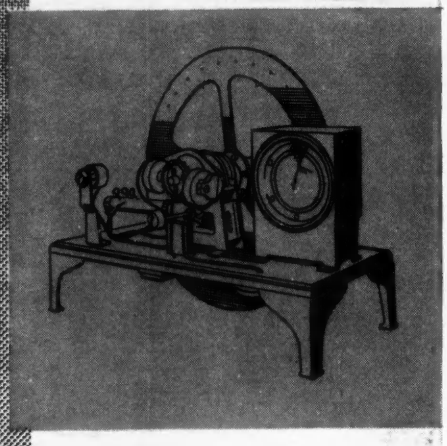

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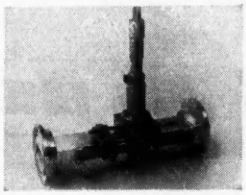

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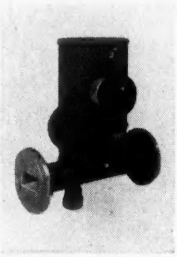

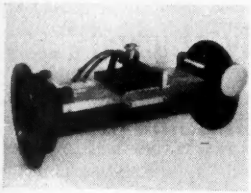

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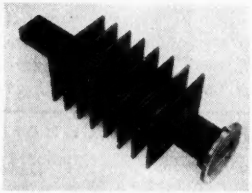

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Vol. 27 JUNE 1955 No. 328

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ELECTRONIC ENGINEERING

VOL. 27 No. 328

JUNE 1955

Commentary

THE death of Professor Albert Einstein at Princeton, New Jersey, on April 18, deprived the world of, perhaps, the greatest scientist of modern times, a man of a stature such as few reach in any generation. Indeed, when looking for a comparable scientific intellect, it is necessary to turn to such as Newton. But Einstein was not only a great scientist, he was a great and good man; a man who believed in, and worked for, peace among men. Yet he was, withal, modest and retiring.

Albert Einstein was born, of Jewish parents, at Ulm in Württemberg in March 1879 and was of comparatively humble beginning, his father having a small electro-chemical factory. His early years were spent in Munich, Milan, Zürich and Berne, and at this time he was far from being an outstanding scholar; he confessed, in fact, to being "extremely stupid" at learning by rote. From the age of 17 to 21 he studied at the Swiss Federal Polytechnic School in Zürich, following the course prescribed for a teacher of physics and mathematics. Owing, in part, to his ancestry, he had difficulty in obtaining a teaching post and in 1902 he was appointed as a technical assistant in the Swiss Patent Office. Three years later, in 1905, while still employed at the Patent Office he made his first major contributions to theoretical physics.

Einstein had earlier simplified Boltzmann's theory of the random motions of the molecules of a gas, and in 1905 he applied this to the "Brownian movement"—the movement of microscopic particles suspended in a fluid, that is caused by molecular bombardment.

In the same year he advanced a new theory of the photo-electric effect which has exercised considerable influence on the modern quantum theory of light. It was, in fact, his work in this field which, seventeen years later, won him a Nobel prize.

It is, however, the theories of relativity with which his name is mainly associated and, in this same momentous year, the "Special Theory of Relativity" was published. In this he deduced, among other things, a relationship between mass and energy and showed the conditions under which one could be converted to the other. For this work he may well be called the "Father of Nuclear Physics", for it is on these facts that the whole of atomic energy and machines such as the synchroton depend.

The "General Theory of Relativity" was published in 1916 and this took into account the effects of gravitation and acceleration, and the bending of light rays by gravity.

From the time of his early publications until 1933 Einstein occupied a number of professorial posts in Europe. In that year the purge of Jewish scientists in Germany decided him to leave the country and he accepted a Professorship at the Institute of Advanced Study at Princeton, a post which he held until 1945.

In 1949 he advanced a "Unified Field Theory" which is an attempt to explain the relationship between all physical laws and, in particular, to establish a mathematical link between the effects of gravity and those of electricity and magnetism. This theory still remains to be proved or disproved and it will, doubtless, be many years before the true worth of the whole of the work of Einstein can be correctly evaluated. That its worth is very great is, however, beyond doubt.

* * *

The official opening of the BBC'S very high frequency transmitters at Wrotham last month is the beginning of a new chapter in sound broadcasting in this country and, at long last, promises improved reception in the London area and South East England.

As is well known, reception of the BBC'S sound broadcasting services has been very unsatisfactory in many areas in this country since the war, due principally to the overcrowded state of the medium and long wave bands. Equally well known have been the BBC's plans to overcome this congestion by the building of a network of v.h.f. frequency modulated stations. These plans were laid down shortly after the war, but economic difficulties prevailing at the time prevented their being put into operation and it is only now that the first of the v.h.f. stations has been brought into regular service.

For those listeners whose reception has been unsatisfactory and whose broadcast receiver is due for replacement, a new v.h.f. receiver will provide the solution. The radio industry has been keeping in step with the BBC during the development of the v.h.f. network, and has provided a range of suitable receivers, some of which made their debut at the Northern Radio Show held in Manchester at the beginning of last month.

The need at the moment is obviously a receiver which will not cost much more than present types, to provide interference-free reception in areas where previously it did not exist.

In the main sets of this type are standard multi-band receivers with an additional band of 88-100Mc/s arranged for reception of the frequency modulated transmissions. As such, they will probably be the general pattern for some time until the industry has "sampled the market."

An Infra-red Radiation Pyrometer

For Measuring the Surface Temperature of Brake Linings

By R. A. Bracewell*

The study of brake performance and the development of brake linings to withstand the high temperatures experienced with modern motor car brakes calls for a means of measuring the actual surface temperature of the friction linings. This article describes the application of the lead sulphide cell to this problem. Pulses of heat radiation are detected as they radiate from the lining through a small slot in the brake drum. These pulses are amplified and displayed on a c.r.t. where they are compared with pulses from calibration lamps. 35mm film records the comparison of the pulses. Lining temperatures of over 1 000°C have been recorded.

IN the investigation of the performance of brakes and brake linings, both on the road and in the test laboratory, it has been usual to note the temperature of the brake drum surface which is in contact with the brake lining.

There are two good reasons why the brake drum surface temperature is a very poor indicator of the duty required from the brake lining:—

(1) Owing to the arc of contact of the lining being roughly only two-thirds of the drum circumference.

(2) Most brake linings are poor conductors of heat and the shoe to which they are attached has very little chance of dissipating heat. On the other hand, the brake drum is a very good conductor and has every chance of dissipating its heat into the surrounding air stream.

Because of these conditions there is a steep temperature gradient on each side of the braking surfaces, but the drum surface is much cooler than the lining surface, especially under dynamic conditions.

It is, therefore, desirable to be able to indicate the actual lining temperature with a detector which has a very rapid response.

Owing to the lining surface being entirely covered by the drum, radiation from the lining through a hole in the drum would appear to be the only method possible. In the past, thermo-couples have been embedded in the lining, but the very high temperature which exists on the surface of the lining cannot be indicated by any indicator below the surface, as the temperature gradient near the surface of the lining must be very steep.

By use of the lead sulphide cell as a detector of radiation, it is possible to detect the radiation on the surface temperature of the lining as it radiates through a ¼in diameter hole in the drum and to obtain a series of sharp pulses which can be calibrated in terms of temperature. The lead sulphide cell is, however, not entirely suitable for use as a direct detector owing to drift and change of sensitivity with change in ambient temperature and also, because the thin film of lead sulphide is easily overheated by strong radiation, causing the cell to be unreliable in these conditions.

If, however, the cell is used as a comparator and only subject to flashes of radiation which will not overheat the film of lead sulphide, then stable results can be obtained and all the advantages of this type of cell can be employed.

These advantages are:—

(1) High sensitivity particularly to infra-red radiation.
(2) High speed of response (40μsec).
(3) Long life.
(4) Simplicity.
(5) Freedom from microphony.

(1) and (2) are particularly important in the present application; high speed of response being very essential to the investigation of the brake lining surface temperatures under dynamic conditions, when the stopping time may be only 3 or 4 seconds and one of several flashes of radiation are to be indicated every revolution of the brake drum. For instance, at 60 m.p.h. using an average size car wheel, the speed of rotation is 775rev/min or 12·9rev/sec, and if one hole is used in the brake drum through which to view the radiation the frequency is nearly 13c/s, and if the one hole is ¼in wide and ½in long the duration of the pulse is approximately 1msec.

(3) and (4) are very desirable characteristics.

(5) Freedom from microphony is very necessary as considerable vibration is bound to be encountered when working with high speeds pressure and deceleration. With the lead sulphide cell vibration does not give any interfering signal as used in this application.

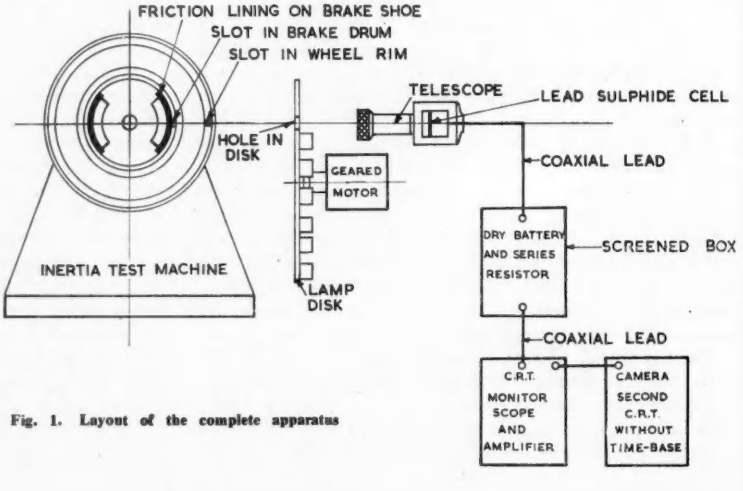


Fig. 1. Layout of the complete apparatus

* *Creswell's Asbestos Co., Ltd.*

A schematic diagram of the complete apparatus is shown in Fig. 1.

The very fact that the radiation is chopped up by being viewed through a hole or holes in the drum overcomes the over-heating of the cell which would be experienced by any direct viewing methods. Except for radiation from the hot drum, which is overcome by having the wheel rim in place with a second slot, which permits only the radiation from the lining to reach the cell.

The use of the cell as a comparator has been achieved by having a series of calibrated lamps rotating and radiating on the cell which give a series of pulses in the form of a step-ladder. These pulses are calibrated in temperature and can be compared with the actual temperature pulses obtained from the surface of the brake lining.

The calibrating lamps, nine in number, are mounted on a disk which is driven by a motor at 167rev/min. The lamp disk is divided into ten equal spaces, nine of which contain a lamp and in the tenth space there is a large hole in the disk. The disk is so arranged that at a turn of the switch it will either rotate, or stop with a hole opposite the telescope from which the cell views the radiation from the brake lining through the hole in the disk and the hole in the brake drum.

The output of the cell is fed into an amplifier and displayed on a cathode-ray tube. The display is photographed by a moving film 35mm camera.

By using the comparator method the sensitivity of the cell or the gain of the amplifier does not affect the calibration, as if these vary they affect the signal and the calibration step-ladder to the same extent, and it is only necessary to adjust the overall sensitivity of the amplifier to give the desired size of the picture from the signal and the calibration will still be correct, although the top of the ladder, i.e. the higher temperatures, may be out of the picture if the signal does not require the full calibration range.

It follows that drift and changing sensitivity, except of very short duration, do not affect the calibration. In the instrument described the calibration range is from 600° to 1 400°C in nine steps of 100°C.

Applying the pyrometer to the flywheel type of test machine, the cell is mounted in a 1in diameter bronze tube of heavy section which is a push fit in the end of the telescope which is focused on the brake lining.

On this test machine, a cycle time switch performs the following operations:—

(1) BRAKE OFF.

(2) CLUTCH IN and motor acceleration.

(3) CLUTCH OUT (free-wheeling).

(4) BRAKE ON.

This cycle can be repeated at any desired frequency from one cycle every ½ minute to as long as required. From CLUTCH IN until just before brake, the calibrating lamp disk is arranged to revolve, and just before BRAKE ON the disk stops with the hole in line with the telescope and the lining. This is controlled by a separate switch on the time switch assembly and is adjustable.

In order to economize in film, the camera is controlled by a hand operated on and off switch to the film drive. Several sweeps of the calibration ladder are taken between stops and the whole of the deceleration signals are recorded.

A second cathode-ray tube without time-base is used for the camera so that the display can be observed continuously on the original scope. Owing to the retardation the temperature signals are not always synchronized on the monitor scope as it is not practical to adjust the time-base frequency during a stop, but this is not of importance as the moving film ensures that the display is correctly formed in the photographs. The speed of response is such that with a film speed of 1in/sec the pulses from the actual lining radiation are sharp vertical lines and it is only on the last revolution or so that these appear to have any width, i.e. when the drum is almost stopped. (See Fig. 2.)

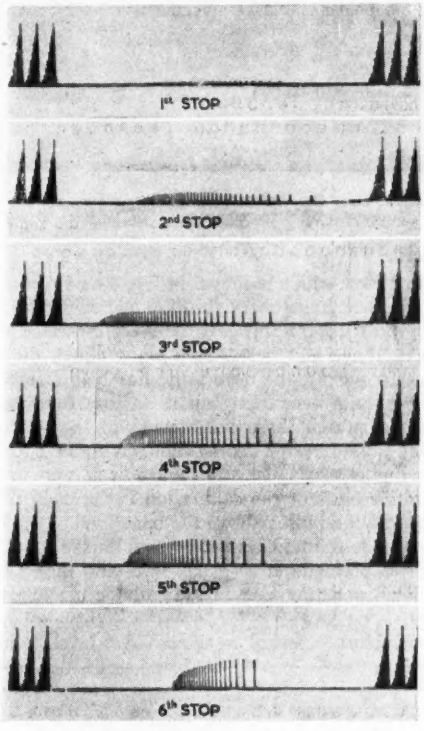


Fig. 2. Series of six stops made from 60 m.p.h.
Maximum temperature on 6th stop is 1 050°C.

Mechanical Set-up

The main details of the mechanical layout are shown in Fig. 1.

A Satchwell Control geared motor was used to drive the lamp disk. Most of the gears were removed to obtain a speed of 167rev/min. The motor is mounted on a channel bracket which carries the telescope, the eyepiece of which can be exchanged for the lead sulphide cell in its holder (see Figs. 3 and 4). This arrangement ensures that the calibrating lamps are always at a fixed distance from the cell. A small motor and switch operated friction drive to the outer edge of the disk is used to arrest the stopping disk and rotate it until the large hole is opposite the telescope. This takes place automatically when the Satchwell motor is switched off. The operation is completely automatic, a special power pack being so arranged that the disk stops just before the brake is being applied and runs again when the flywheel is accelerated for the next stop.

This assembly is mounted on a radial bracket which can be rotated so as to view any part of the lining and so we are able to observe the temperature over the full length of the lining, which owing to the geometry of the shoe, would be expected to show different results.

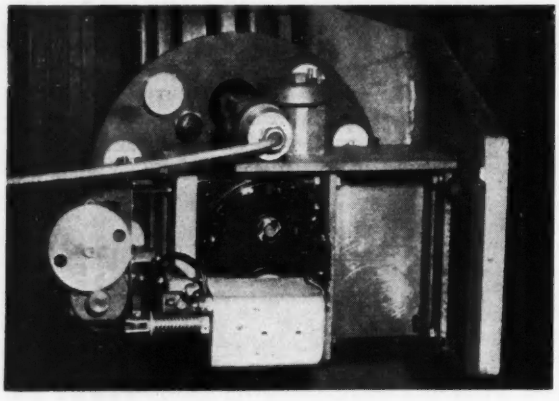


Fig. 3. The lamp disk viewed from the rear showing the cell in its mounting

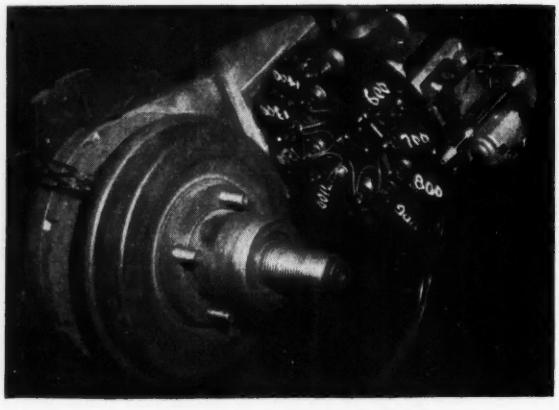


Fig. 4. The brake drum and lamp disk

Amplifier

The amplifier, which is shown in Fig. 5, is direct coupled, this arrangement giving a straight base line to the pulses. *RC* coupling was tried, but this gave the effect illustrated in Fig. 6. The areas above and below zero being equal, the shorter the pulse frequency, the deeper the line below zero. D.C. restoring circuits were tried, but it was not found possible to obtain a straight base line, owing to the variation in frequency caused by the deceleration. With a d.c. coupling, the base line is very satisfactory and this is most important as the whole basis of the calibration is the comparison of the height of the pulses above the base level.

The cathode-follower valve V_1 enables the input to the amplifier to be made at zero d.c. level and the adjustment of the 50kΩ potentiometer in the cathode of V_1 gives this condition.

As the volume control is at zero d.c. level, adjustment of this control does not affect the position of the trace, on the c.r.t. provided the d.c. level control is correctly adjusted.

The 120V dry battery and 820kΩ series resistor are housed in a screened box to avoid 50c/s pick-up and connected to the cell and the amplifier by coaxial cable with plugs and sockets.

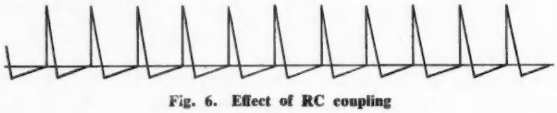


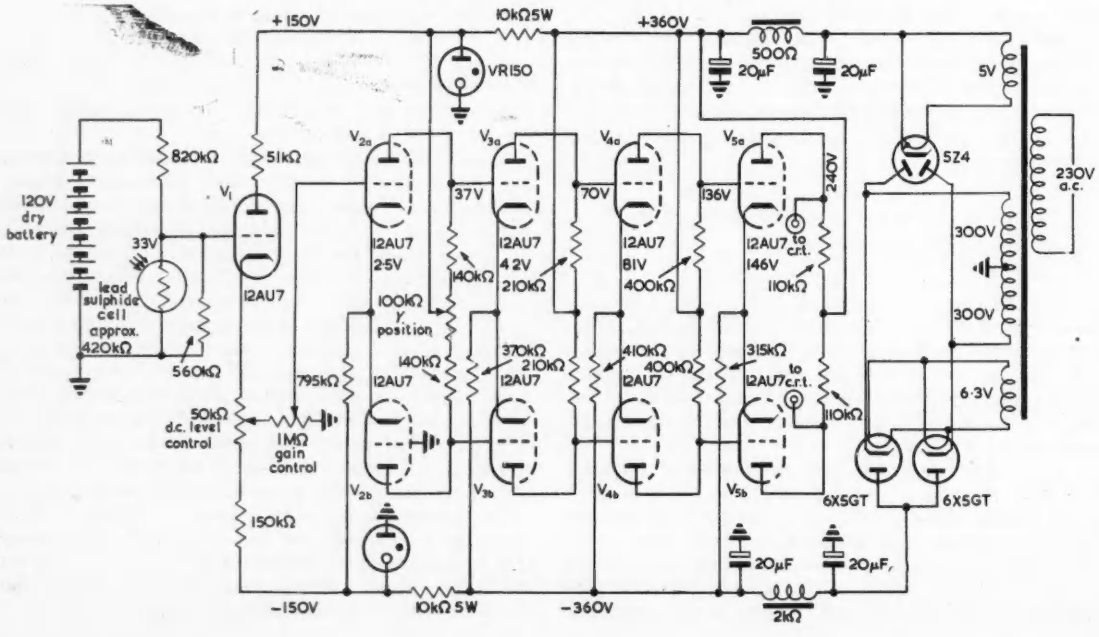
Fig. 6. Effect of RC coupling

The 560kΩ grid resistor on V_1 is placed on the valve leg to chassis and earth, and while this reduces the signal, it also entirely eliminates any 50c/s hum.

The amplifier is fairly free from drift, but slight drift is not important in this application, as the Y position con-

Fig. 5. The amplifier circuit

The lead sulphide cell is a B.T.H. type M2. All resistors are high stability type.



trol can be adjusted to give a central picture on the monitor-scope just before photographs are taken.

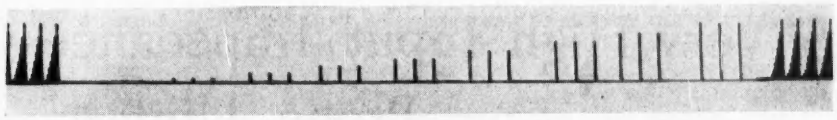


Fig. 7. Print of film of calibration of infra-red pyrometer 600°C to 1400°C in 100°C steps
Centre part is signal from platinum heat source. Step ladder on each side is signal from lamps.

Calibration

For this purpose the drum and wheel rim were set up on a lathe with the open side of the drum towards the saddle and the pyrometer with calibrating disk was set up at a given distance from the brake lining surface, in this case (7in). A heat source was used in place of the lining and this consisted of a piece of platinum foil 0·001in thick, about ½in wide and 1½in long, which was mounted in a U-shaped holder and as near the drum as possible. This was so arranged that both sides of the platinum can be used, one side to radiate in the same manner as the heated brake lining and the other side can be inspected by an optical pyrometer to check the temperature of the heat source.

The platinum is heated electrically, 2V giving a maximum true temperature of approximately 1 400°C and taking about 45A. This current is fed from a 230 to 2V transformer and an auto transformer gives the necessary control of the platinum foil temperature. The readings of the optical pyrometer (Foster Disappearing Filament type 2571/3000) were corrected for black body conditions. The lowest reading on the Foster Optical Pyrometer is 700°C and the current through the platinum was found to be linear with corrected temperature so that by continuing the current to temperature graph the calibration was extended down to 600°C and then by direct observation up to 1 400°C in 100°C steps.

Calibration was taken with a brake drum speed of 165rev/min. All the lamps but the one to be adjusted to give a calibration of 1 400°C were masked and the heat source was adjusted to 1400°C (true temperature) and the lamp variable resistor adjusted to give the same signal, which was set at 2in deflexion on the tube by adjustment of the amplifier gain; each lamp was so adjusted in turn against the corresponding calibration temperature of the platinum source.

The results were checked by taking a series of photographs of the display of the heat source and the corresponding lamp, as the observation of the pulses on the cathode-ray tube cannot be done with precision.

The hole in the brake drum was ¼in wide and ½in long and a corresponding hole was made in the wheel rim. The reasons for having the wheel and rim in place were to ensure that the cooling on the test machine was the same as on the road, and to give a flat base line to the trace on the cathode-ray tube—if the cell were to look at the hot drum the base line of the trace would be deflected when the temperature of the drum rises high enough to be detected by the cell and as the height of the pulses above the base line is the basis of the calibration, it is convenient to use the rim as a shield from the hot drum. In addition, a fan is geared to the main drive so as to blow air on the drum at a velocity equal to road speed.

35mm film was taken of the pulses of the heat source and of the lamps. This was projected on to graph paper in order to check the pulse heights. (See Fig. 7.) Table 1 gives the results.

A nomogram based on Wiens formula and supplied by Elliot Bros. (London) Ltd. was used to convert from observed temperature to true temperature.

TABLE 1

TEMPERATURE	IMAGE HEIGHT (mm.)		ERROR (mm.) + or −	PERCENTAGE ERROR
	PLATINUM FOIL HEAT SOURCE	LAMPS		
1 400	212	205	−7	−3·3
1 300	169	171·5	+2·5	+1·5
1 200	142·5	145	+2·5	+1·8
1 100	112·5	113	+0·5	+0·45
1 000	84	84·5	+0·5	+0·59
900	59	61	+2	+3·4
800	37	37	Nil	—
700	22	20·5	−1·5	−6·9
600	10	10	Nil	—

Table 2 shows the relation between true temperature, observed temperature, and current through the platinum.

TABLE 2

TRUE TEMPERATURE (°C)	OBSERVED TEMPERATURE (Black Body Conditions) (°C)	CURRENT (A)
600	590	21·9
700	675	24·4
800	760	27·0
900	840	29·4
1 000	935	30·0
1 100	1 020	34·6
1 200	1 115	37·5
1 300	1 195	40·2
1 400	1 285	44·5

Brake Drum and Radiation Slot

Drum 9in diameter, 1½in wide.

Slot ¼in by ¾in formed by drilling two ¼in round holes ½in apart and opening out to a slot.

Considering a ¼in band around the drum:

Area of plain band ..	6·88in	97·6 per cent
Area of slot	0·17in	2·4 per cent
	7·05 in	100 per cent

The reduction in area of the drum of 2·4 per cent is not considered large enough to affect the results; actually, this would result in a slightly lower lining temperature, but is so small that it is felt it can be disregarded.

Heater Circuit for Calibration Lamps

These are run from a.c. through a 6V transformer fed by a constant voltage transformer.

A sensitive rectifier voltmeter is provided and a resistance to set the input to the lamp circuit to 5V.

Acknowledgments

The author wishes to thank Mr. C. Kinsey, managing director of K. R. S. Radio Ltd, Shipley, Yorks, for his assistance with the electronic circuits and reading the proofs, and also Mr. L. J. Davies and Mr. B. N. Watts, B.Sc., of B.T.H. Co. Ltd, for their assistance and information on their research with the lead sulphide cell.

A Very High Input Impedance Oscilloscope Probe Unit

By G. O. Crowther*, B.Sc., A.C.G.I.

This article describes a probe unit with a very high input impedance primarily developed to assist in investigations into the behaviour of cold-cathode trigger valves. It is capable of responding to large and rapid potential changes. The output is suitable for direct connexion to an oscilloscope or to a voltmeter to give a direct reading of the mean d.c. potential at the input. The probe unit should have many applications in other spheres of work either as an oscilloscope probe or a high impedance voltmeter.

IN nearly all investigations into the behaviour of cold-cathode tubes operating under dynamic conditions, it is essential to be able to measure the potential and observe potential changes of electrodes which have a very high impedance to earth. The impedances involved are generally too high to permit direct connexion of an oscilloscope or standard moving-coil voltmeter and may have a value anywhere in the range 10^6 to $10^{12}\Omega$.

The probe unit has been made up in two sections: (1) a small input probe, and (2) the main unit and output section. In order to obtain a compromise between speed and input impedance requirements, two types of probe heads have been designed with the following general characteristics: (a) very high input impedance with a comparatively slow speed of response, and (b) high speed of response but with a lower input impedance.

The circuits have been designed to meet the following specification:

Input Impedance

The input should be regarded as a constant current generator in parallel with a very high leakage resistance. In practice, the leakage resistance is very high and may be neglected compared with the constant grid current, which for the fast probe is 10^{-9}A, and for the high impedance probe 2×10^{-13}A.

Voltage Input Range

The probe is capable of measuring direct voltages in the range -300 to $+650$V and will respond to a rapid change of 200V anywhere in the above d.c. range.

Speed of Response

The high speed probe responds to a rate of change of $50\text{V}/\mu\text{sec}$, while the high input impedance probe responds to a rate of change of $5\text{V}/\mu\text{sec}$.

General

Accuracy of voltage measurement is ± 1 per cent for voltages greater than 100V. Below this voltage it is ± 1V. The input capacitance is in the region of 1pF, and the output impedance of the order of 150Ω. The drift of zero setting is 0·3V in the first half hour, further changes being less than 0·1V.

Basic Circuit

The circuit employed is essentially a cathode-follower using an electrometer-type valve to obtain the required high input impedance. Because of the small permitted anode voltages, an electrometer valve cannot be employed in a simple cathode-follower circuit giving a wide range of input voltages. The maximum anode voltage for the ME1401 is 10V. This small anode voltage limits the input variations to a few volts. Circuits of high input impedance voltmeters which have overcome this difficulty have been described in the literature[1, 2]. These circuits may be adapted to an oscilloscope probe unit, and Figs. 1 and 2 show series and parallel arrangements respectively.

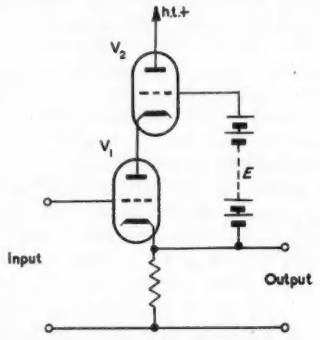


Fig. 1. Series circuit

Consider first the circuit shown in Fig. 1. The valve V_1 is an electrometer valve, and V_2 is a normal receiving-type valve. Both V_1 and V_2 are wired as cathode-followers, V_2 having V_1 as a cathode load. The first cathode-follower V_1 acts as the signal input and output in the normal manner. The function of the second cathode-follower V_2 is to maintain the anode-to-cathode voltage of V_1 at a constant value E independent of the input voltage. The input to the grid of V_2 is taken from the output of V_1 with the constant voltage E superimposed. This circuit therefore retains the very high input impedance associated with the electrometer valve for the wide range of input voltages for which the cathode-follower V_2 maintains the anode-to-cathode voltage of V_1 substantially constant.

The maximum rate of change of the input voltage to which the circuit is capable of responding is set by the maximum permissible current of the electrometer valve V_1 and the stray capacitance to earth at the cathode of V_1. (This capacitance includes the stray capacitance to earth of the battery E.) If this maximum rate of change is exceeded, for a negative change, V_1 is cut off and the output voltage falls to the new steady value at a rate determined by the circuit. For a rise in excess of the maximum value, the valve takes excessive current and the

* *Mullard Radio Valve Co. Ltd.*

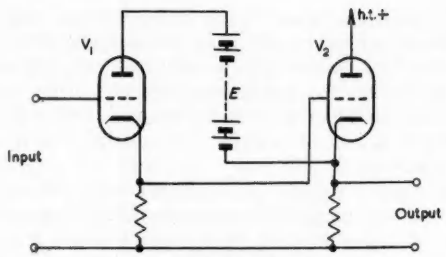


Fig. 2. Parallel circuit

input impedance is considerably reduced owing to grid current. The maximum rate of change dV/dt, either positively or negatively, may be calculated from the expression

$$\frac{dV}{dt} = \frac{I_{max}}{2} \cdot \frac{1}{C}$$

where I_{max} is the maximum permitted current of the electrometer valve

and C is the total stray capacitance.

In a mains-operated circuit, the stray capacitance C may be as large as 500pF and the maximum permissible current of a ME1401 is 100μA. This gives a maximum rate of rise or fall of 0·1V/μsec, which is considerably below the required performance.

However, a substantial gain in the speed of response may be obtained by using the circuit of Fig. 2. In the circuit of Fig. 2, V_1 is again an electrometer valve and V_2 a normal receiving-type valve. Both valves are again wired as cathode-followers, but in this case V_1 acts only as the signal input while V_2 acts as the signal output as well as providing the constant anode-to-cathode voltage for V_1. The large stray capacitance due to the battery E and any capacitance added at the output terminal in this circuit are charged and discharged by the comparatively large currents of V_2, which has not the stringent input impedance requirement of V_1. The speed of response of this circuit is again limited by the stray capacitance at the cathode of V_1, but by careful design this may be kept below 20pF, a factor of 20 to 30 below that of the series circuit. This parallel circuit is the basic circuit of the final probe unit.

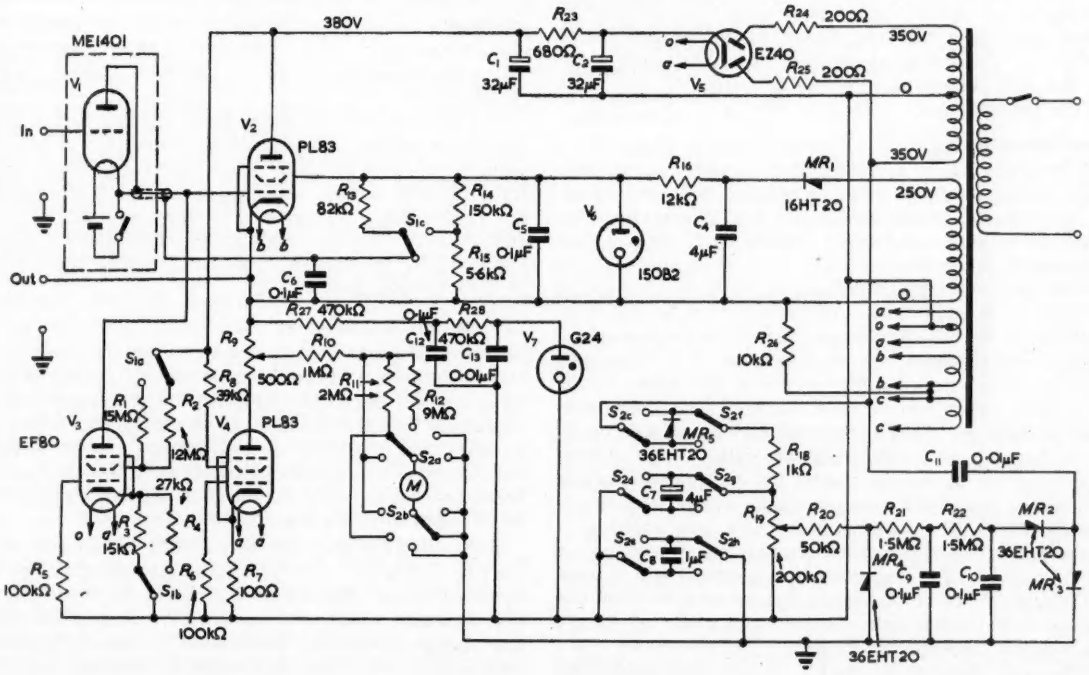
Details of the Complete Circuit

The complete circuit of the probe unit is shown in Fig. 3. A number of additions to the basic circuit of Fig. 2 have been necessary in order to obtain the performance required. These additions are discussed in the following sections.

Current Generator (V_3 and V_4)

It has been shown in the previous section that the unit will retain the very high input impedance of the electrometer valve provided the second cathode-follower V_2 maintains the anode-to-cathode voltage of the electrometer valve V_1 substantially constant over the operating range. The working anode voltage of an ME1401 electrometer valve is about 9V, and therefore anode voltage changes of about 1 or 2V only can be tolerated over the complete working range: this represents a required gain of at least 0·99 for the second cathode-follower V_2. A constant current generator V_4 has been added to maintain the cathode current of V_2 constant, and a floating stabilized voltage has been connected between screen and cathode of V_2 in order to obtain this required gain. It is only possible to obtain a gain of the order of 0·9 with the simple circuit shown in Fig. 2.

Fig. 3. The complete probe unit



A second constant current generator V_3 has also been added to maintain the cathode current of V_1 constant. This current generator is not essential to maintain the high input impedance, but has been added to give a greater overall gain to the circuit, and therefore give greater accuracy of measurement. It also considerably simplifies the anode voltage supply E for V_1, which is obtained from the V_2 screen voltage supply. This will be discussed in greater detail in a later section.

"SET D.C. LEVEL" (R_{19})

To obtain the maximum speed of response from the circuit, and to ensure that the electrometer does not receive excessive transient anode voltages when sharp voltage changes are applied to the input, the output cathode-follower must be capable of a more rapid response than the input cathode-follower V_1. To obtain the required speed of response, in spite of the large stray capacitance at the cathode due to the floating screen supply, the cathode current of V_2 must be at least 20mA. To obtain the wide operating range quoted in the specification, a valve with high values of g_m and r_a capable of withstanding an anode-to-cathode voltage of 1·2kV with an anode dissipation of 24W is required. No such valve was available, and for this reason it has been necessary to use the PL83 and to keep the maximum anode-to-cathode voltage of V_2 below 300V, restricting the range of operation to 200V on the input. This would be a severe restriction on the use of the probe, as it would only allow variations of ± 100V about a predetermined voltage. To obtain a wider range of operation, arrangements have been made to vary the predetermined voltage by floating the whole circuit on a variable supply connected between the negative line of the circuit and earth. The variable supply is made up of MR_5, C_7, C_8, R_{18}, R_{19} and R_{20}, the rectifier MR_4 is part of a protection circuit, and normally may be regarded as a direct connexion to earth. The voltage is varied by the potentiometer R_{19} and may be either positive or negative, dependent on the position of switch S_2. This additional circuit allows the centre value of the 200V operating range to be varied to any value in the voltage range -200 to $+600$V.

THE PROBE HEADS

Two probe heads have been designed for use with the main unit, a very high input impedance probe and a high speed probe. As stated earlier, this was to obtain a compromise between the input impedance and speed of response requirements.

The very high input impedance probe is shown in detail in Fig. 3. It employs an ME1401 for the electrometer valve V_1. The small filament battery employed is the "penlite" size Mallory mercury cell RM 502. These cells have a useful working life of about 150 hours in the circuit. A larger battery could be employed, but unless care is taken the speed of response may be reduced owing to a larger stray capacitance to earth. Under normal conditions the electrometer valve has an anode-to-cathode voltage of about 10V and an anode current of approximately 50μA. The input impedance is best stated as a constant current fed into the circuit under investigation of 2×10^{-13}A. This current, which is due to grid current, is independent of input voltage changes over the operating range, since the electrode potentials and anode current are maintained substantially constant.

The high speed probe head is similar to the high input impedance probe except that a selected EF86, connected as a triode, is used for the electrometer valve. The valve is run with a heater voltage of 5·5V, taken from the winding *cc* on the mains transformer. Under normal conditions the anode-to-cathode voltage is 80V, the anode current 1mA, and the current fed into the circuit under test approximately 10^{-9}A.

The heater voltage of the EF86 has been lowered from 6·3 to 5·5V to reduce the component of grid current due to grid emission. However, with the 1mA of anode current, the grid current is mainly due to gas current and therefore no further reduction in this current can be obtained by reducing the heater voltage to the 4·5V normally recommended for electrometer applications. A considerable fall in speed of response would also be experienced with a heater voltage of 4·5V owing to the low cathode emission.

It should be noted that in order to obtain the very small values of grid current quoted above for the EF86, the valve should be aged for a period of at least 30 minutes at an anode current of 1mA if it has been idle for a period in excess of a few days. This is necessary to clean up the small quantities of gas which are liberated under idle conditions and which would cause excessive grid current for this application.

As stated earlier, the anode voltage for the electrometer valves is obtained from the floating screen voltage supply for V_2. Since the anode current to the electrometer is maintained constant over the operating range, the required anode voltage can be obtained by inserting a dropping resistor from the 150V screen voltage line in series with the anode of V_1. If the electrometer current is not kept constant, it is necessary to add a further stabilizer to obtain a steady anode voltage for the high speed probe head. The capacitor C_6 maintains the anode voltage constant during a rapid input voltage change. It should be noted, particularly in the case of the high impedance probe, that the grid-to-cathode voltage of V_2 also forms part of the anode-to-cathode voltage of V_1. The required anode voltage and current is selected by the switch S_1.

The output from the probe head is taken to the main unit via a coaxial cable; the inner conductor carries the input to V_2 and the outer conductor the anode voltage for V_1. There is very little loss in the speed of response due to this long lead, since the voltage between the inner and outer conductor is maintained substantially constant and therefore the effective capacitance seen by the cathode of V_1 is almost zero.

THE OUTPUT CIRCUIT

The oscilloscope output is taken from the cathode of V_2, as in the basic circuit, and is suitable for direct connexion to any standard oscilloscope. The effective output impedance is approximately 150Ω. It should be noted, however, that owing to an electrometer valve protection circuit erroneous results may be obtained if a d.c. path is connected between the output terminal and earth which takes a d.c. current in excess of 50μA.

An indicator circuit has been added to indicate when the "set d.c. level" control is set to give the centre of the operating range. The circuit is a simple gas diode relaxation oscillator, which indicates when the output to negative line voltage exceeds the breakdown voltage of the diode. The limits to the operating range occur when either of

the valves V_2 and V_4 is driven into the "knee" of its anode characteristic, i.e. when the output to the negative line voltage is either 90V or 380 − 90 = 290V. A small indicator diode has been selected with a breakdown voltage of 180V which is equivalent to the centre of the operating range.

Owing to the limited d.c. load which may be applied to the output, a voltmeter with a 100μA movement has been incorporated in the units made up for the laboratory to give a direct indication of the mean voltage at the input. This meter has the following voltage ranges: 0 to 100, 0 to 300, 0 to 1 000, 0 to −300, 0 to −100V. The meter resistors were made up of high stability resistors wired as shown in Fig. 3 to keep the effective stray capacitance at the cathode of V_2 as low as possible. The voltmeter circuit is taken from the potentiometer R_9 connected in series with the valves V_2 and V_4 to obtain a correction for the constant positive voltage which exists between the input and the cathode of V_2. This positive voltage is equal to the sum of the grid-to-cathode voltages of V_1 and V_2. The potentiometer R_9 is employed as the "set zero" control and is normally set with the circuit operating at the centre of the operating range.

The accuracy of voltage measurements is about 1 per cent for all voltages in excess of 100V, either positive or negative, at any point in the operating range. The accuracy of measurement for voltages below 100V is dependent on the position in the operating range at which the measurement is made, and is about ±1V under the worst conditions. An accuracy of 1 per cent can, however, be obtained for these voltages if the measurement is made at the same point in the operating range at which the "set zero" control was set. Under these operating conditions the voltages and currents existing in the circuit are substantially the same as those present when the "set zero" control was set. This may be readily carried out by taking the measurement and setting zero at the centre of the operating range as indicated by the neon indicator.

The Electrometer Valve Protection Circuit

Under certain conditions of input and settings of the "set d.c. level" control, it is possible for the electrometer valve to pass several milliamperes of grid current. To prevent damage to the electrometer valve, a protection circuit has been added to limit the grid current under these conditions to 200 to 300μA.

Consider for the present that the rectifier MR_4 is short-circuited and the input to the probe is connected to a low impedance supply of, say, 600V. The circuit will behave as already described, provided the "set d.c. level" control is correctly set. However, if this control is set such that the valve V_2 is driven well into the "knee" of its anode characteristic, then the constant current from the anode of V_4 cannot flow to the anode of V_2, but flows to the grid of V_1, via the grid of V_2. This grid current is only limited by the resistor R_{19} and may be as large as 3 or 4mA. The rectifier MR_4 is connected such that under the above conditions it presents a very high impedance between earth and the potentiometer, R_{19} limiting the grid current to a safe value. Under normal conditions of use, the rectifier is held in its low impedance condition by a small forward current from a negative supply made up of MR_2, MR_3, C_9, C_{10}, C_{11}, R_{21}, R_{22}.

The grid current which flows under the above conditions with the rectifier in the circuit is given by the expression

$$i_g = i_f + \frac{E_{in}}{R} - \frac{E_s + 300}{R} - i_{dc}$$

where i_f is the forward current in the rectifier MR_4 under normal conditions.

E_{in} is the input voltage.

E_s is the voltage existing between the common negative line and the cathode end of the rectifier MR_4 (the "set d.c. level" voltage).

R is the effective resistance between the common negative line and earth (the back resistance of the rectifier MR_4 in parallel with the effective d.c. resistance of the negative supply (MR_2, MR_3, etc.).

i_{dc} is the magnitude of any current flowing from the output terminal to earth due to the meter or other d.c. path.

It will be seen from the above expression that it is desirable to keep the normal forward current i_f of the rectifier MR_4 as small as possible. However, it is essential that this forward current exceeds the maximum value of any current i_{dc} which may exist. This current will vary dependent on the meter range or other d.c. paths connected to the output. The return path for these currents is through the rectifier and the direction of flow is the same as for the grid current. Therefore, if the forward current of the rectifier is insufficient, the rectifier will present a high impedance even under correct operating conditions, causing unreliable results.

Zero Drift

The zero drift during the first half hour is 0·3V and afterwards is less than 0·1V using the high speed probe. There is an additional drift when using the high input impedance probe owing to the slow discharge of the filament battery. This drift is about 0·3V for a change of battery voltage from 1·25 to 1V. In practice, using the Mallory cell, this is not serious.

Construction

The main unit is housed in a small Imhof case type 1 050 measuring 10in × 7in × 6in. The probes are made up in small paxolin cases measuring 1¾in × 1¼in × 3¾in for the high speed probe and 2¾in × 1⅜in × ⅝in for the high input impedance probe. The input insulation of both probe heads is made up of polished polystyrene to obtain the high insulation required. Protective metal plates have been placed in front of the polystyrene, spaced a small distance away, to prevent fingerprints, etc., appearing on the polished surface.

Conclusion

This probe unit should have many applications, not only in the cold-cathode field but also in any application where high impedances are encountered and where it is required to observe rapid voltage changes on an oscilloscope. The probe unit has been invaluable in all investigations on cold-cathode trigger tubes where the impedances encountered are often greater than 1MΩ.

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A Design Method For Direct-Coupled Flip-Flops

By W. Renwick*, M.A., B.Sc., and M. Phister*, Ph.D.

A method is developed for designing a flip-flop which will be stable with a given tolerance on resistors, voltage supplies and valve characteristics, which is a requirement for a flip-flop for use in a high-speed digital computer. It is shown that when the supply voltages are not fixed by other considerations the principal time-constant of the circuit can be minimized by properly choosing the supply voltages. The method is applicable to all direct-coupled switching circuits.

A FLIP-FLOP or bistable trigger circuit which is to be used in an electronic computer must satisfy two important conditions:

(a) *Stability*: changes in the characteristics of valves or of other circuit parameters must not affect the stability of the flip-flop. In particular, a flip-flop built from standard (that is, not specially selected) valves and resistors must be stable, and variations of the characteristics of these components within certain limits should not make the circuit unstable.

(b) *Speed*: when changing from one state to the other the circuit must reach equilibrium in as short a time as possible. Furthermore, it is usually desirable that all transients die out in the interval between the end of one switching pulse and the beginning of the next.

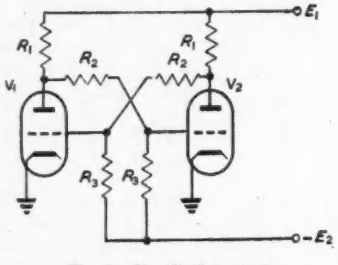


Fig. 1. The flip-flop circuit

The purpose of this article is to describe a systematic method for designing the flip-flop of Fig. 1 for use in an automatic computer. This circuit was chosen from the number of well-known flip-flop circuits because of its simplicity and symmetry.

The design problem will be solved in three stages. First, non-varying components will be assumed and an "ideal" flip-flop developed. Second, the circuit will be redesigned so that it remains stable when resistors, valve characteristics and h.t. voltages vary within certain limits. Both of these problems assume that E_1 and E_2 are fixed, and that values must be given to R_1, R_2, and R_3. Finally, a method will be developed for choosing E_1 and E_2 so that the principal time-constant of the circuit is minimized, and the resulting "optimum" flip-flop is still stable regardless of parameter variations within the given tolerances.

* *The University Mathematical Laboratory, Cambridge.*

The Ideal Flip-Flop

The conditions for stability of the circuit of Fig. 1 can be taken to be:

$$V_{g2}' = \frac{E_1R_3 - E_2(R_1 + R_2)}{R_1 + R_2 + R_3} \geqslant 0 \quad \ldots\ldots (1)$$

$$V_{g1} = \frac{(E_1 - i_aR_1)R_3 - E_2(R_1 + R_2)}{R_1 + R_2 + R_3} \leqslant E_c \quad \ldots (2)$$

Here V_{g2}' is the voltage that the grid of V_2 would reach if that valve did not draw grid current and E_c is the cut-off voltage of V_1 when its anode is at voltage E_1. If the valves are identical and corresponding resistances are equal, as shown, the equations ensuring stability of the other state are the same as equations (1) and (2).

Two other relationships completely define the flip-flop. The first connects the anode voltage of the conducting valve with the other circuit parameters.

$$V_{g1} = \frac{V_aR_3 - E_2R_2}{R_2 + R_3} \leqslant -E_c \quad \ldots\ldots\ldots (3)$$

The final requirement is some information about the valve characteristic, although for the purposes of flip-flop design, it is not necessary to know the entire characteristic. If the circuit is operating correctly, each valve is either cut off or conducting heavily. If it is conducting, and equation (1) holds, grid current must flow. The grid voltage will be a function of the grid-current/grid-voltage characteristic of the valve, and at the limit of equation (1) will be slightly negative. The effect of grid current is shown in Fig. 2. The anode-current/anode-voltage characteristics for this grid voltage only need be considered, and in general this may be taken as the zero-grid bias characteristic. Even this curve will be eliminated from the present analysis, and a single point on it taken to contain the given data. Exactly how and why this point is chosen will be discussed later.

In the ideal case, resistances and voltages remain fixed and equations (1), (2), and (3) may be written as equalities rather than inequalities. In other words, the circuit is designed so that grid voltages lie at exactly zero and $-E_c$. The three equations may then be solved for i_aR_1, R_1/R_2, and R_1/R_3, the results being:

$$i_aR_1 = E_c(1 + E_1/E_2) \quad \ldots\ldots (4)$$

$$R_1/R_2 = E_1(E_2 - E_c)/E_2(V_a + E_c) - 1 \quad \ldots\ldots (5)$$

$$R_2/R_3 = (V_a + E_c)/(E_2 - E_c) \quad \ldots\ldots (6)$$

R_1, R_2, and R_3 may now be calculated from equations (4), (5), and (6). However, in order to use these equations, V_a and i_a must first be determined from the valve characteristics. Generally speaking, a fast-switching flip-flop requires that R_1 be as small as possible, and for that reason i_a and therefore V_a must be chosen to be as large as possible. There is, however, a limit on the magnitude of V_a. Since the ratio of two resistances must be positive, we can set equation (5) greater than zero and solve for V_a:

$$V_a < E_1 - E_c(1 + E_1/E_2) \quad \ldots\ldots\ldots\ldots \quad (7)$$

The entire design procedure may now be stated. First V_a and i_a are chosen from the zero-grid-bias characteristic, with V_a as large as possible subject to equation (7) and to the maximum permissible cathode current or anode dissipation of the valve. E_c is chosen as the cut-off voltage corresponding to anode voltage E_1, and finally R_1, R_2, and R_3 are calculated from equation (4), (5), and (6).

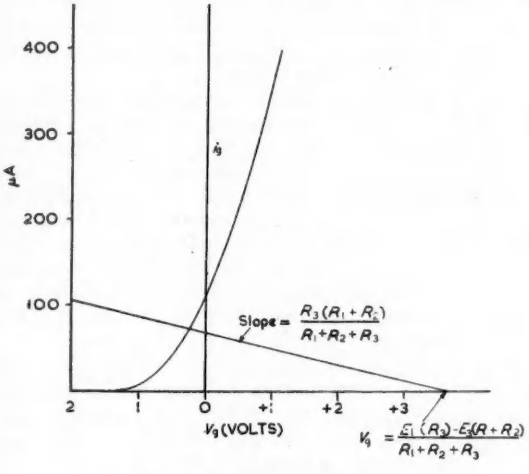


Fig. 2. The effect of grid current

If such a circuit were practical, the time taken for it to change state would be very short. This time has been calculated by Tillman[1].

A Practical Flip-Flop

A practical flip-flop is built with resistors and valves whose characteristics are determined only within certain tolerances, and it must operate with voltage supplies which change by an amount depending on the degree of stabilization provided. In this section a flip-flop will be designed which will be stable when built with resistors varying by $\pm p$ per cent of their nominal values, which will operate with voltages E_1 and E_2 each of which may change independently by $\pm q$ per cent; and which uses a valve whose characteristics may vary over a wide range.

Typical variations in characteristics for a group of supposedly identical double triodes (CV455 = ECC81) and pentodes (CV138 = EF91) are shown in Fig. 3. If a flip-flop is to be stable using any of these valves, it must be stable using the "worst" one, which is the valve with the smallest anode current for a given anode voltage. Consequently, in the following analysis V_a is the anode voltage corresponding to an anode current in the worst valve. Exactly how V_a and i_a are chosen depends to some extent on p, q, E_1, and E_2 as will be explained below.

Supposing for the moment that V_a and I_a have been chosen, it is necessary to derive equations corresponding to (1), (2), and (3) that make the circuit stable even when all resistors and voltages have the worst possible values. The grid voltage of the conducting valve, given by equation (1), is lowest when E_1 and R_3 are low, and E_2, R_1, and R_2 are high. Under these circumstances we want the grid

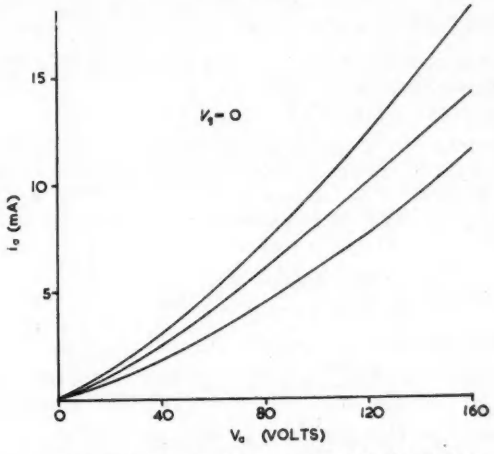


Fig. 3(a). Variation of anode characteristic of CV445 (ECC81)

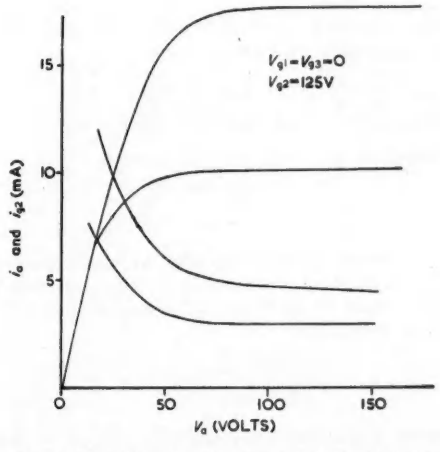


Fig. 3(b). Variation of anode characteristic of CV138 (EF91)

voltage to be greater than zero, or in the limit exactly equal to zero. That is,

$$\frac{E_1R_3(1-p)(1-q) - E_2(R_1+R_2)(1+p)(1+q)}{(R_1+R_2)(1+p)+R_3(1-p)} \geqslant 0 \quad \ldots \quad (8)$$

On the other hand, the grid voltage of the cut off valve is highest when E_1 and R_3 are high, and E_2, R_1, and R_2 low. Under these conditions the grid voltage must be less than or equal to $-E_c$:

$$\frac{R_3(1+p)[E_1(1+q) - i_aR_1(1-p)] - E_2(R_1+R_2)(1-p)(1-q)}{(R_1+R_2)(1-p)+R_3(1+p)} \leqslant -E_c \quad \ldots \quad (9)$$

$$\frac{V_a R_3(1+p) - E_2 R_2(1-p)(1-q)}{R_2(1-p) + R_3(1+p)} \leqslant -E_c \quad \ldots (10)$$

These three inequalities may be solved as follows: from equation (8) we can write:

$$(R_1 + R_2)/R_3 = R_2/R_3(1 + R_1/R_2) = \frac{E_1(1-p)(1-q)}{E_2(1+p)(1+q)} \quad (1 - \delta_1) \ldots\ldots\ldots (11)$$

where $\delta_1 \geqslant 0$.

Solving equation (9) for $i_a R_1$, and substituting $(R_1 + R_2)\, R_3$ from equation (11) we get:

$$i_a R_1 \geqslant E_c(1 + k_1 E_1/E_2)/(1-p) + k_2 E_1 + \frac{k_1 E_1 \delta_1 (1 - q - E_c/E_2)}{1-p} \ldots\ldots\ldots (12)$$

where $k_1 = \dfrac{(1-p)^2(1-q)}{(1+p)^2(1+q)}$

and $k_2 = \dfrac{4(p+q)(1+pq)}{(1+p)^2(1-p)(1+q)}$

From equations (10) and (11) we find

$$\frac{k_1 k_3 E_1/E_2}{1 + R_1/R_2} \geqslant R_2/R_3 \geqslant \frac{k_3(V_a + E_c)}{E_2(1-q) - E_c} \ldots\ldots (13)$$

where $k_3 = (1+p)/(1-p)$,

and from the first and last parts of this inequality we find

$$1 + R_1/R_2 = \frac{E_1 k_1 (E_2(1-q) - E_c)}{E_2(V_a + E_c)}(1 - \delta_2) \ldots (14)$$

where $\delta_2 \geqslant 0$.

Substituting from (14) into (11)

$$R_2/R_3 = \frac{k_3(V_a + E_c)(1 - \delta_1)}{(E_2(1-q) - E_c)(1 - \delta_2)} \quad \ldots\ldots (15)$$

and comparing this with (13) we see that

$$1 - \delta_1 \geqslant 1 - \delta_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

As in the case of the ideal flip-flop, we must choose V_a, i_a and E_c before using equations (11), (12) and (14). If we set R_1/R_2 equal to zero in (14), noting that $\delta_2 \geqslant 0$, it is possible to solve for V_a:

$$V_a < \frac{k_1 E_1 (E_2(1-q) - E_c)}{E_2} - E_c. \quad \ldots\ldots (17)$$

The design procedure is therefore as follows.

(a) Choose V_a and i_a to be as large as possible, subject to equation (17) and the maximum cathode current or anode dissipation of the value. E_c is the cut-off voltage corresponding to anode voltage E_1.

(b) Find a minimum value for R_1, using equation (12) but neglecting the last term, since δ_1 is not known.

(c) From equation (14), find the minimum value for R_2 with the R_1 calculated in step (b).

(d) Taking R_2 larger than this minimum, try various standard values for R_2 and R_3, making δ_1 in equation (11) positive and as small as possible.

(e) A tentative choice of R_1, R_2, and R_3 may be confirmed by making sure that:

(1) $1 - \delta_1 \geqslant 1 - \delta_2$

(2) The addition of the term $\delta_1 K_1 E_1/(1-p)\,[1 - q - E_c/E_2]$ to $i_a R_1$ does not make necessary a larger value for R_1 than that chosen in step (b).

EXAMPLES

We shall design two flip-flops using the triodes of Fig. 3(a), and two more with the pentodes of Fig. 3(b). In each case we shall assume that $E_1 = 150$V and $E_2 = 300$V.

(a) $p = q = 0{\cdot}05$. Substituting E_1, E_2, q, p, and $E_c = 10$V into equation (18) we find, for the triode, $V_a < 92$V. Choosing $V_a = 80$V and $i_a = 4{\cdot}5$mA, we calculate $i_a R_1 \geqslant 60$V from equation (12). With $i_a = 4{\cdot}5$mA, the nearest 5 per cent resistor satisfying this relationship is $R_1 = 16$kΩ. Next, from equation (15) we find $R_1/R_2 \leqslant 0{\cdot}1315$, and therefore $R_2 \geqslant 121$kΩ; we must then choose R_2 and R_3 from the available resistor values so that equation (11) is satisfied. By a process of trial and error we find $R_2 = 160$kΩ and $R_3 = 430$kΩ, and from these calculate that

$$1 - \delta_2 = 0{\cdot}9725 \qquad 1 - \delta_1 = 1{\cdot}00$$

therefore equation (16) is satisfied, and since $\delta_1 = 0$ no extra term need be added to $i_a R_1$.

For the pentode we choose an operating point at the knee of the "worst" expected valve: $V_a = 50$V, $i_a = 9{\cdot}5$mA. Using equation (12) we find $i_a R_1 \geqslant 61{\cdot}8$V, and with $i_a = 9{\cdot}5$mA the nearest 5 per cent standard resistor satisfying this relationship is $R_1 = 6{\cdot}8$kΩ. Next, from equation (14) we find $R_1/R_2 < 0{\cdot}885$ so that $R_2 > 8$kΩ. By trial and error, we arrive at $R_2 = 30$kΩ, and $R_3 = 91$kΩ, whence $(1 - \delta_1) = 0{\cdot}988$ and $(1 - \delta_2) = 0{\cdot}65$. Therefore $1 - \delta_1 > 1 - \delta_2$, and since $\delta_1 = 0{\cdot}012$ the last term in equation (12) adds only about 1·5V to $i_a R_1$, and this does not necessitate an R_1 greater than 6·8kΩ.

(b) $p = q = 0{\cdot}10$. Applying equation (17) again, we find, for the triode, $V_a < 61$V. Choosing $V_a = 50$V and $i_a = 2{\cdot}5$mA, we get $R_1 = 47$kΩ, $R_2 = 620$kΩ, and $R_3 = 2$MΩ. For the pentode, with $V_a = 50$V and $i_a = 9{\cdot}5$mA as before, we get $R_1 = 12$kΩ, $R_2 = 56$kΩ, and $R_3 = 220$kΩ.

These results are summarized in Table I.

TABLE 1

	p	q	V_a (V)	i_a (mA)	R_1 (kΩ)	R_2 (kΩ)	R_3 (kΩ)
Triode ..	·05	·05	80	4·5	16	160	430
	·10	·10	50	2·5	47	620	2 000
Pentode ..	·05	·05	50	9·5	6·8	30	91
	·10	·10	50	9·5	12	56	220

$E_1 = 150$ V. $E_2 = 300$V.

Switching Time

It has been mentioned that the ideal flip-flop, whose grids swing only between 0 and $-E_c$ volts, has a very small switching time, since both valves conduct during the entire transient. A practical flip-flop, on the other hand, may have a grid swing many times E_c. For example, in the 5 per cent triode flip-flop designed in the example of the last section, if R_1, R_2, and E_2 have values at the high end of their allowed range, and R_3 and E_1 values at the low end, and if the valve used has a very low anode resistance, the grid voltage may swing from zero to -72V. The switching time of such a circuit, then, is largely taken up by the swing of one or both grids below the cut-off level, the excursion of voltages through the grid base occupying only a very small proportion of the total time.

Fig. 4 shows a simple form of compensation intended to improve the switching properties of the flip-flop. In that figure, C_1 and C_3 are the stray capacities measured at anode and grid, respectively, and C_2 is an added "compensating" capacitor. The value of C_2 chosen depends on what transient characteristic the designer wants. A large compensating capacitance results in a circuit which very quickly changes from one stable state to the other, but introduces a long time-constant which greatly increases the time taken for the transient to die out and therefore decreases the repetition rate at which the flip-flop may be triggered.

Rubinoff[2] has shown that when $R_1C_1 < R_3C_3$ (which is invariably the case) and when $R_2C_2 = R_3C_3$ the flip-flop reaches equilibrium most quickly without the introduction of a long-time constant. The resulting switching time depends to some extent on the method used to trigger the flip-flop. The usual method involves a negative voltage pulse at either the grid or anode of the circuit, and Rubinoff showed that under this condition the most

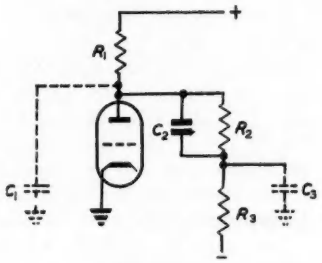


Fig. 4. Simple form of compensation

important transient which occurs during switching has a time-constant

$$T = \frac{R_1C_3\,[1 + C_1/C_3(1 + R_2/R_3)]}{1 + R_1/R_3 + R_2/R_3} \quad \ldots\ldots\ldots \quad (18)$$

It should be noted that the non-linearity due to the diode action at the grid re-introduces a long time-constant into the voltage waveform at the grid. However, since the time taken for the grid of the non-conducting valve to rise to cut-off is in general the longest time involved in the transition of the flip-flop, the time-constant given in equation (18) is still valid as a measure of the switching time of the circuit.

The Optimum Flip-Flop

If E_1 and E_2 are fixed, we have seen that equations (11), (12), and (14) determine the resistors and therefore the time-constant of the circuit. In this section we make E_1 and E_2 variable, and derive an "optimum" flip-flop by minimizing T. Two cases will be considered. In the first case E_c will remain constant corresponding to a flip-flop built with pentodes with fixed screen voltage. In the second E_c will be a function of E_1 corresponding to a triode flip-flop. Equalities rather than inequalities will be assumed, so that $\delta_1 = \delta_2 = 0$.

(a) *The Pentode flip-flop.* Setting $R_2/R_3 = y$ and $1 + R_1/R_2 = x$, from equation (11) we have:

$$E_1/E_2 = xy/k_1k_3 \quad \ldots\ldots\ldots\ldots \quad (19)$$

Solving equation (13) for E_2 and substituting into equation (19):

$$E_1 = \frac{xy}{k_1k_3(1-q)}\left\{\frac{k_3(V_a + E_c)}{y} + E_c\right\} \quad \ldots\ldots\ldots \quad (20)$$

Now substituting from equation (19) and (20) into equation (12), and the resulting value for R_1 into equation (18):

$$T = \frac{E_cC_3}{i_a(1-p)}\left\{\frac{1+C_1/C_3(1+y)}{1+xy}\right\}\left\{1+xy/k_3\left[1+\frac{k_2(1-p)}{k_1(1-q)}\right]\right. + \left.\frac{xk_2(1+V_a/E_c)(1-p)}{k_1(1-q)}\right\} \quad \ldots\ldots \quad (21)$$

It can be shown that this expression for T is a minimum when x is a minimum for all positive values of y. When unity is substituted for x in equation (21), the resulting expression for T has a minimum value when y is given by:

$$y_c = \sqrt{\left[C_3/C_1\left(\frac{2p}{1-p} + \frac{4V_a(p+q)(1+pq)}{E_c(1-p^2)(1+q)^2}\right)\right]} - 1 \quad \ldots\ldots\ldots\ldots \quad (22)$$

Substituting this value for y, and unity for x into equation (21) gives:

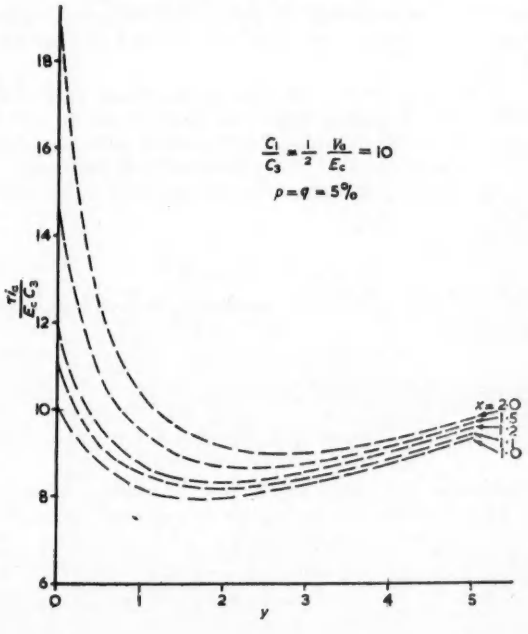
$$T_{min} = \frac{E_cC_3(1+p)(1+q)^2}{i_a(1-p)^2(1-q)^2}\left\{1+\sqrt{\left[C_1/C_3\left(\frac{2p}{1-p} + \frac{4V_a(p+q)(1+pq)}{E_c(1-p^2)(1+q)^2}\right)\right]}\right\}^2 \quad \ldots\ldots \quad (23)$$

y_c as given by equation (22) is negative when:

$$C_1/C_3 > \frac{2p}{1-p} + \frac{4V_a(p+q)(1+pq)}{E_c(1-p^2)(1+q)^2}$$

In this case y should be made as small as possible to

Fig. 5. Variation of time-constant with x and y



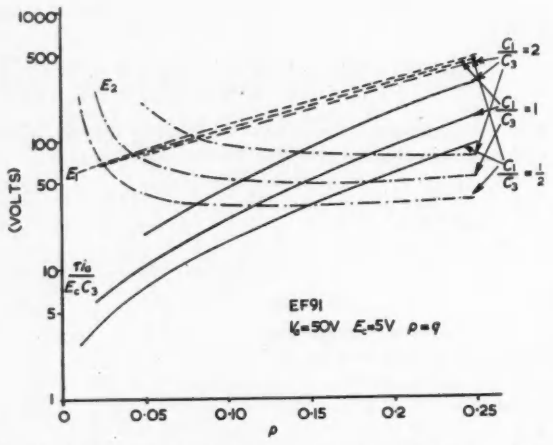


Fig. 6. Variation of minimum time constant and supply voltages with p

minimize the time-constant which is given by:

$$T_{min} = \frac{E_c C_3(1+p)(1+q)^2}{i_a(1-p^2)(1-q)^2}(1+C_1/C_3) \times \left(1 + \frac{2p}{1-p} + \frac{4V_a(p+q)(1+pq)}{E_c(1-p^2)(1+q)^2}\right) \ldots\ldots (24)$$

when unity and zero are substituted for x and y respectively in equation (21).

Examination of equation (23) and (24) shows that the time-constant increases with E_c and V_a/E_c and decreases with i_a. It follows, therefore, that the best operating point on the pentode characteristic is at the knee. Fig. 5 shows the variation of the time-constant with x and y of a flip-flop built with EF91's, taking $V_a/E_c = 10$ and $C_1/C_3 = \frac{1}{2}$, and using 5 per cent resistors and allowing 5 per cent variation in the voltage supplies. In Fig. 6 the minimum time-constant is plotted against p for the same type of valve for three different values of C_1/C_3, and for equal tolerances on resistors and voltage supplies. The required voltage supplies, calculated from equations (19) and (20) are also shown.

(b) *The Triode Flip-Flop.* The cut-off voltage of a triode depends on the anode voltage, and therefore, for the circuit under discussion, on $E_1R_2/(R_1+R_2)$, which is the maximum voltage on the anode. The relationship between anode voltage and cut-off voltage may be assumed to be linear and here we will take:

$$E_c = E_1/\mu \frac{R_2}{R_1+R_2}$$

Again writing the variables as x and y we have from equation (11):

$$E_1/E_2 = xy/k_1k_3 \ldots\ldots\ldots\ldots (25)$$

and from equation (20) substituting for E_c:

$$E_1 = \frac{xk_3V_a}{\mu k_1k_3(1-q)-k_3-y} \ldots\ldots\ldots (26)$$

Substituting into equation (12), and the resulting value for R_1 into equation (18) we find the time-constant given by:

$$T = \frac{V_aC_3}{i_a(1-p)}\left\{\frac{x\mu k_2k_3(1-p)+xy+k_3}{\mu k_1k_3(1-q)-y-k_3}\right\}\left\{\frac{1+C_1/C_3(1+y)}{1+xy}\right\} \ldots\ldots\ldots\ldots (27)$$

As in the case of the pentode flip-flop it can be shown that the time-constant is a minimum when x is equal to unity and y is given by:

$$y_o = \frac{\sqrt{[AB(1+(B-A)C_1/C_3)]} - A}{1+B\,C_1/C_3} - 1 \ldots\ldots (28)$$

where $A = \frac{2p}{1-p} + \frac{4\mu(p+q)(1+pq)}{(1-p^2)(1+q)}$

and $B = \frac{(1+p)(1+q)}{1-p}$

From equation (27) it is obvious that the time-constant increases as V_a/i_a increases and, therefore, to make the time-constant minimum, the operating point should be chosen where this ratio is a minimum. Since most triodes have anode characteristics which are concave upwards, V_a and i_a are usually chosen to be as large as possible consistent with the maximum power and current ratings for the valve. As in the pentode case, when y_o is negative E_2 should be chosen to be as large as possible.

The procedure for designing an optimum flip-flop may now be stated. Firstly, the operating point is chosen according to the approach given above. Secondly y_o is calculated from equation (22) or equation (28), remembering that a negative value of y_o indicates that E_2 should be as large as possible. With this value of y_o and some estimate near unity for x, E_1 and E_2 are found from equations (26) and (25) in the triode case and equations (20) and (19) in the pentode case. With the supply voltages chosen, the flip-flop may be designed using the method detailed.

Conclusions

Though this article has treated the design of one particular circuit in considerable detail, certain of the results have general and important implications. In the first place, the circuit, though it incorporates no negative feedback, can be made as stable as desired. That is to say, it can be designed to remain stable for any voltage and resistor variations (with the proviso that equation (18) holds, and that $E_2(1-q) > E_c$), and for any group of valves having any specified minimum characteristic.

In the second place, an increase in stability is invariably accompanied by a decrease in switching speed. This can be looked on as a gain-bandwidth limitation, for stability corresponds to gain, and transient response to bandwidth. The effect of increasing tolerances is particularly noticeable in equation (24), which expresses the optimum pentode time-constant in terms of valve constants and tolerances.

Finally, it has been shown that the switching speed for a given degree of stability is a function of the supply voltages used, and can be minimized by suitably adjusting these voltages. This would seem to be true generally for all direct-coupled circuits and designers of direct-coupled circuits should keep in mind that the choice of proper supply voltage levels may have as much effect on transient response as the provision of higher switching currents.

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A Ringing Choke Power Supply

By J. Houldsworth*

A stabilized e.h.t. power supply giving an output voltage adjustable between 1 and 2kV for load currents up to about 1mA was needed in connexion with a cathode-ray tube data storage system. The unit was required to give a steady output when operated from a.c. mains, the voltage of which might vary by ± 10 per cent. Good stabilization was necessary against both slow and rapid changes in the load, and the output voltage was required to be free from 50c/s and other ripple. It is shown below that the above requirements can be met by using a pulse type power supply, in preference to rectifying a 50c/s voltage derived from the a.c. mains, and details are given of a unit of the "ringing choke" type which was developed. The complete unit operates satisfactorily in the application for which it was intended, and it is believed that it may find other applications as a general purpose stabilized e.h.t. power supply.

IT is important that the e.h.t. supply should be free from 50c/s or any other ripple which may interfere with the cathode-ray tube data storage system for which it is intended. The conventional method of obtaining a steady voltage by rectifying and smoothing the output from a mains transformer is not very satisfactory due to the difficulty in eliminating 50c/s ripple from the output. On the other hand, a high frequency pulse operated power unit presents very little difficulty in this direction and the pulse source can, if necessary, be synchronized with the operating frequency of the storage elements. Fig. 1 shows the circuit diagram of a power unit which has been developed to meet the requirements outlined.

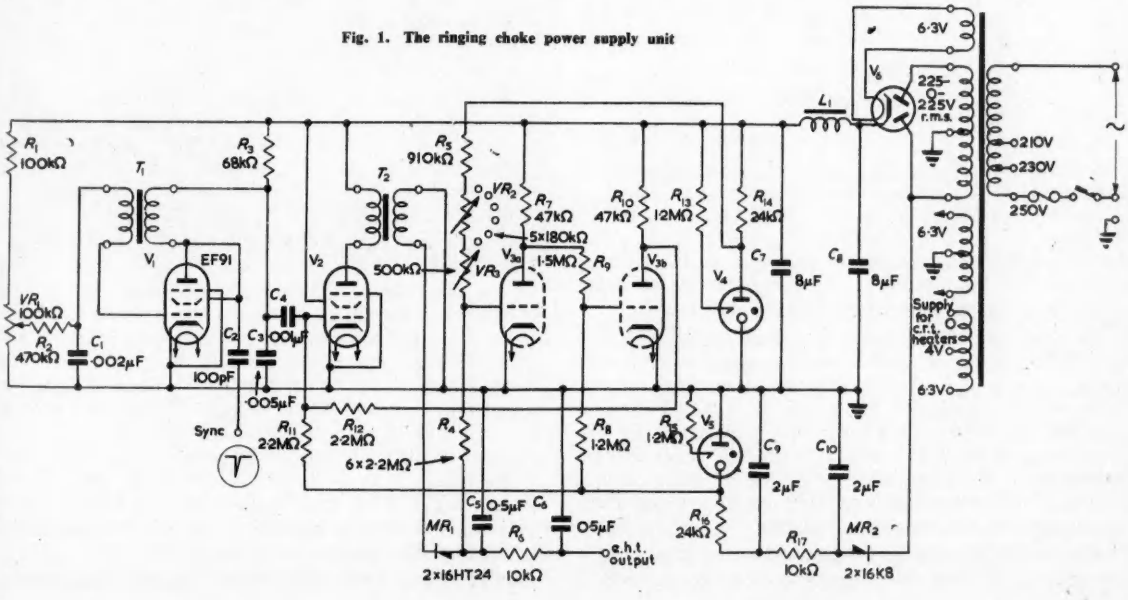
The pentode V_1 is triode-connected and operates in a free running blocking oscillator circuit. The recurrence rate of the oscillator is about 3kc/s; it may be varied over a small range by means of VR_1. The blocking oscillator may be locked to the scan frequency of the c.r.t. store by injecting 10V negative pulses at the synchronization terminal. In this way radiated interference and ripple due to inadequate smoothing can be made to occur within the flyback time of the storage cathode-ray tube time-base.

V_1 conducts for only a few microseconds during the blocking oscillator cycle; during the short conducting period it forms a low impedance discharge path for C_3. When the valve is cut-off C_3 recharges through R_3. Due to the rapid charge and slow discharge of C_3, the voltage at the grid of V_2 is of sawtooth waveform.

Each time C_3 is discharged, the potential of the grid of V_2 falls rapidly, causing a sudden interruption in the current carried by the primary winding of T_2. The rapid change in the current in the primary winding of T_2 induces a voltage of high initial amplitude across the secondary winding of the transformer. This voltage is rectified by MR_1 and applied to C_5, C_6 and R_6 forming a low-pass filter to give a steady voltage across the output terminals. On account of the slow rise in the grid potential of V_2, caused by the relatively long recharge time of C_3, the anode current of V_2 increases gradually; this is done to prevent a voltage of opposite sense being produced by the trans-

* *Ericsson Telephones Limited.*

Fig. 1. The ringing choke power supply unit



former. If such a reverse voltage were produced, it would only increase the peak inverse voltage across the rectifier to an extent which might cause breakdown, without producing any additional rectified output.

The output voltage varies with the voltage induced in the secondary winding of T_2, and consequently it varies with changes in magnitude of the current step in the primary winding. The maximum anode current of V_2, which determines the amplitude of the current step in the primary winding, may be controlled by variations in the mean potential of either the control grid or the screen.

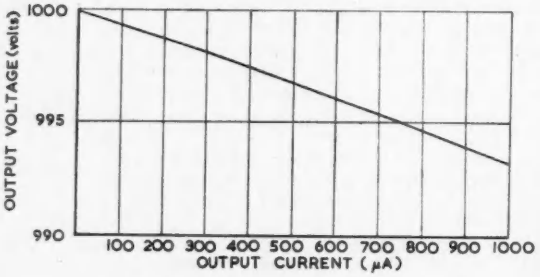


Fig. 2. Output voltage/output current
Unit set for 1 000V at no load.

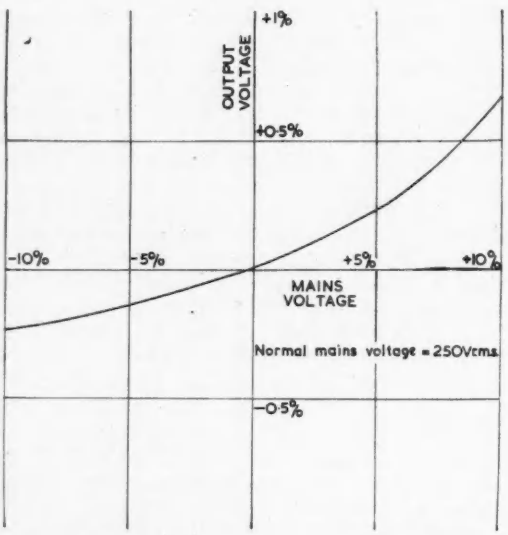


Fig. 3. Variation of output voltage with mains voltage
Mains voltage and output voltage variations expressed as a percentage of 250V r.m.s., and 1 000V respectively.

To obtain the required output voltage range, the mean potential of the screen, grid 2, must be varied between wide limits; since grid 2 draws an appreciable mean current, these potential variations could only be obtained from an amplifier stage which has a low output impedance. For the same range of rectified output voltage, only small changes are needed in the mean potential of grid 1: since no grid current flows the potential variations can be obtained from an amplifier of high output impedance.

The relationship between e.h.t. voltage and the grid 1 potential of V_2 was investigated to find the upper and lower limits of grid 1 potential necessary for the desired e.h.t. output range, which is 1kV to 2kV for load currents between 100μA and 1mA.

The potential at the grid of V_{3a} in the d.c. amplifier is a function of the setting of VR_2 and VR_3, and of the voltage across the output terminals. The mean grid-1 potential of V_2 is set by the control amplifier, and component values are so chosen that the extreme settings of VR_2 and VR_3 correspond to the desired limits of e.h.t. voltage. Using one-half of a double triode for each amplifier stage, sufficient gain is available to give satisfactory operation over the designed output range.

To ensure that the unit is insensitive to mains voltage fluctuations, reference potentials of +150V and −150V with respect to earth are provided. These auxiliary supplies are obtained from the main +250V and −250V lines and are stabilized by cold cathode tubes. The +150V supply acts as a reference voltage for the dividing network across the output, while the −150V supply provides bias for the control d.c. amplifier.

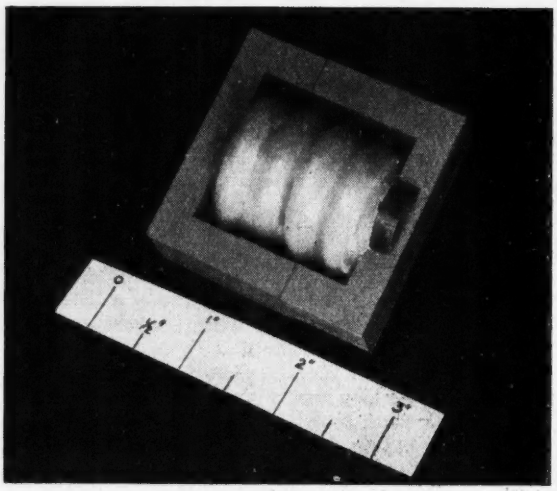


Fig. 4. Encapsulated pulse transformer with laminations

The +250V supply is obtained from a mains transformer and conventional full wave valve rectifier circuit. A half-wave metal rectifier connected to the same secondary winding of the mains transformer is used to obtain the −250V supply, which is smoothed by a resistance-capacitance filter circuit.

The complete unit has been tested to determine the variation of output voltage over the design range of load current and mains voltage. Curves plotted using the results obtained and reproduced in Figs. 2 and 3 demonstrate the performance of the power unit in the above circumstances. The maximum ripple voltage across the output terminals at any setting of the controls is 30mV, which is 0·03 per cent of the minimum output voltage. This is far less than the percentage ripple obtained across the output of a conventional mains e.h.t. power unit unless uneconomic sizes of smoothing components are incorporated. Apart from the size and cost of these components, the energy stored in the larger smoothing capacitors needed for 50c/s smoothing is undesirably greater.

An additional advantage of this type of supply unit is

in the ease of construction of the transformer producing the e.h.t. voltage; in a 50c/s supply the number of turns required is such that a large transformer core and bobbin must be used to provide space for the winding plus insulation. In this unit which operates with pulses at 3kc/s, the e.h.t. transformer requires 650 turns on its primary, in the anode circuit of V_2, and 1950 turns on its secondary winding; these can easily be included in the window area of a type 410 lamination. In this case, the necessary insulation can be provided by constructing the secondary as three wave-wound "pies", supported on an insulating tube carrying the primary, which for convenience is a single wave-wound coil; details of the construction can be seen in Fig. 4. The secondary winding develops a maximum

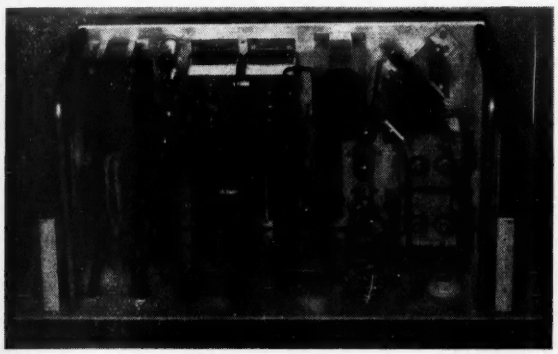


Fig. 5. Rear view of the complete unit

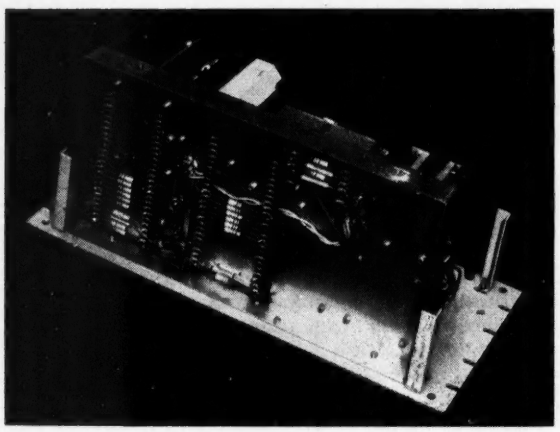


Fig. 6. Underside view of the complete unit

of just over 2kV peak; as the winding is divided into three, the maximum voltage between sections is only 700V peak, and the distance between the sections is sufficient to withstand this voltage. Further protection is provided for the completed winding by complete encapsulation to provide a smooth moisture-resisting surface. The construction of the complete power supply unit is shown in Figs. 5 and 6.

Acknowledgments

The author wishes to thank the Directors of Ericsson Telephones Ltd. for permission to publish this article.

Appendix

Transformer Winding Details:

Mains Transformer

Wound on bobbin SSK 5839 using 1¼in stack of type 440A laminations.

Primary	
250V r.m.s. 50c/s	1 557 turns of 0·01in dia. s.s.c.e. copper wire, tapped at 1 308 and 1 432 turns. Resistance = 85Ω approx. Voltage regulation on full load = 12V approx.
Secondaries	
H.T. 225V - 0 - 225V 60mA full load current	0 - 1 539 - 3 078 turns of 0·0068in dia. s.s.c.e. copper wire. Resistance = 407Ω approx. Voltage regulation on full load = 12V approx.
L.T.1 3·15V - 0 - 3·15V 1·4A full load current	0 - 22 - 44 turns of 0·028in dia. s.s.c.e. copper wire. Resistance = 0·2Ω approx. Voltage regulation on full load = 0·3V approx.
L.T.2 0 - 6·3V 0·6A full load current	43 turns of 0·02in dia. s.s.c.e. copper wire. Resistance = 0·2Ω approx. Voltage regulation on full load = 0·3V approx.
L.T.3 0 - 4V - 6·3V 1A full load current	0 - 27 - 43 turns of 0·024in dia. s.s.c.e. copper wire. Resistance = 0·2Ω approx. Voltage regulation over the whole winding on full load = 0·3V approx.

Smoothing Choke

Approximately 5 000 turns of 0·0084in dia. s.s.c.e. copper wire wound on bobbin SSK 5837, using a ¾in stock of type 401A laminations.

Inductance = 15H approx.
Resistance = 500Ω approx.
Air-gap = 0·007in approx.

Pulse Transformer

Former: A bakelite insulating tube of external diameter 27/32in, internal diameter ¾in and length 1¾in. The former is partially milled away at one end to admit a ½in stack of type 410 radiometal laminations with an air-gap of approximately 0·007in.

Primary: 650 turns of 0·004in d.s.c. copper wire, wound as a "pie" of ¼in width and 1¾in overall diameter.

Secondary: 3 "pies", each of 650 turns, wound in series with dimensions approximately the same as the primary.

Spacing between primary and secondary windings, and between the "pies" of the secondary winding is approximately ¼in.

The complete winding is totally encapsulated in bakelite varnish.

Wirewound Resistors

Some Practical Considerations in design of the types used in the Electronic Industry

By R. H. Mapplebeck*

An outline of some of the physical constituents that affect the design and construction of low wattage wirewound resistors is followed by a discussion of factors that also have to be taken into consideration, including the elimination of undesirable effects, when such resistors are used in a.c. circuits up to about 20Mc/s.

MODERN electronic techniques demand close tolerances in many respects, and maintaining a high degree of accuracy and stability in the manufacture of wirewound resistors means paying close attention to details which, though they may be unimportant where wider tolerances would be satisfactory, become prime factors for consideration in more delicately balanced equipment.

It is proposed to deal with some of these and indicate some of the factors governing the design of this humble yet essential component which can so easily be produced in values ranging from near zero to about 10^6 ohms, and adjusted to cover a wide range of conditions.

Rating

The current carrying capacity of a wirewound resistor depends in large measure on how rapidly the heat can be dissipated. In cases where a resistor may be poorly ventilated, it is usual to allow for about one-quarter of the nominal rating though a well ventilated resistor may be run at a much higher temperature. Apart from ventilation, rating is controlled by proximity to other hot components, ambient temperature, and even fire regulations. Long resistors will run hotter than short ones, and tappings will reduce the effective heat radiation.

When designing a resistor for a particular job therefore, these points should be borne in mind and also that Ohm's law is adequate only when the resistor is to be used in d.c. and l.f. alternating current circuits.

In a.c. circuits, due allowance must be made for losses of energy due to the formation of electromagnetic and electrostatic fields that vary with time and introduce:

1. Eddy current losses in conductors and other masses of metal in or near the circuit.
2. Hysteresis losses in magnetic materials.
3. Dielectric losses in insulation mediums.
4. Absorption of energy by neighbouring conductors due to induction or even radiation.

Skin effect also increases the resistance due to non-uniform current density and so the Joulean relationship $P = I^2R$ is only effective where P is the power loss due to all causes.

Although resistors may be designed to carry heavy currents and dissipate considerable energy, their use in electronic instruments is usually limited to fairly low values of power dissipation and the maximum energy losses seldom exceed 10 watts.

* *Marconi Instruments Ltd.*

As cooling will in many cases be by air convection, the heat loss will depend primarily on the surface area and it is usual to allow from 0·005 to 0·01 watt dissipation per degree centigrade per square centimetre above air temperature.

Temperature

Power rating and the effects of heat on resistance are bound up with the choice of wire material and its behaviour with change in temperature which, together with the current to be carried and the possible physical dimensions required will decide the gauge of wire to be used for a particular purpose.

For d.c. working, the resistance $R = \rho(l/a)$, where ρ is the resistivity of the wire material, l the length and a the cross-sectional area.

Now the resistance of a conductor being a function of its temperature, and having decided on the dimensions of the conductor and its resistance per unit length, the required value may be computed at the temperature for which it applies. Within ordinary limits $R_{t_2} = R_{t_1}[1 + \alpha(t_2 - t_1)]$ where α is the temperature coefficient of resistance of the wire material per °C and may be ascertained by reference to a set of suitable tables, while t_1 and t_2 are the initial and final working temperatures in °C respectively.

For accurate results, resistors are usually wound with constantan, manganin or eureka wire on account of their low temperature coefficients, their constancy of resistance and except in the case of constantan, their low thermo-electric effects with copper. Manganin, although excellent for all low temperature work is not so useful as eureka at higher temperatures. Nichrome on the other hand, although possessing a slightly higher temperature coefficient may be run at red heat (1 000°C) without noticeable oxidation.

In a.c. circuits, residual capacitance must be kept low if the material surrounding the wires is a poor dielectric, as the dielectric constant will alter quite appreciably with temperature changes. Dissipation of energy in a poor dielectric will therefore be reduced if the C_0 is kept low.

Stability

No wirewound resistor will keep its initial value of resistance with time unless subjected to ageing, which may be regarded as an annealing process designed to remove strain from the wire.

During winding, the inner surface of the wire suffers some compression due to bending of the conductor, while the outer surface becomes subjected to tension. If no ageing process is carried out, in course of time the displaced material tends to creep back to its original position which

causes a change in resistance of the conductor by an amount which may be as much as 0·5 per cent. Manufacturers' ideas on the subject of ageing differ somewhat, but in general, baking for three hours duration at a temperature of 150°C is sufficient, though some engineers advocate 24 hours at about 120°C.

Occasionally it is found advisable to make cyclic heat runs under actual operating conditions where the annealing is carried out on the resistor after assembly in the equipment for which it is to be used. That is to say, the heat generated by the normal working current is that which anneals the wire material. In this case, periodic checks have to be made on the resistance value until no further change takes place indicating that the resistance has reached a stable condition. Such a heat run may easily occupy several days before stability is realized.

Formers and Protective Coatings

Most resistors are given a protective covering, the nature of which depends on the temperature at which they are designed to work. The composition of the formers will also be affected by temperature and must be chosen for this and other qualities which are enumerated later on in the text and apply particularly if they are to be used in a.c. circuits where absorption of moisture by a dielectric will give a change in C_0.

Resistors may be wound on ceramic formers, strips of fibre, bakelite, mica, cores of textile or glass fibre. Obviously, ceramic and mica formers will be the most heat resistant, though heat is not the only criterion. Windings must be protected from mechanical injury, electrolytic effects and corrosion due to moisture and bacteria.

Common among such protective coverings are vitreous enamel, cement with organic or inorganic binding materials, moulded bakelite, waxes and paper. Here again, heat decides the covering to a great extent. Up to 250°C the first two mentioned are good for humidity protection without deterioration, but it is worthwhile noting that sodium silicates are useless for protection against moisture. Moulded bakelite may be used up to temperatures of 175°C depending upon the quality of the binding material; resinous binders are superior to asphalt binders for moisture resistance, though they will not stand such high temperatures.

A.C. Circuits

Skin effect imposes considerable modification in design and it is essential for the designer to know the equivalent a.c. resistance of a given wire sample at specific frequencies. The current crowds in a thin layer on the outside of a conductor, but if two cylindrical wires are parallel to one another then at high frequencies the currents concentrate on the parts of them which are nearest and is known as proximity effect[1].

It has been shown by Butterworth[2] that the resistance of a cylindrical wire at frequency f is given by:

$$R_f = R_0[1 + F(z)]$$

where R_0 = resistance to d.c.

$z = \sqrt{(8\pi^2 a^2 \mu f/\rho)}$

a = radius of wire.

μ = permeability.

ρ = specific resistance.

Copper, eureka and manganin have $\mu = 1$ and for the purpose of skin effect and eddy currents, the resistance is calculated in electro-magnetic units, one ohm being 10^9 e.m.u. Now with ρ for copper $= 1{\cdot}7 \times 10^{-6} \times 10^9 = 1\,700$ and manganin 44 000. Table 1 gives values of $F(z)$ against z.

For $z < 2$, $F(z) = z^4/192$

$z > 3$, $F(z) = \frac{1}{4}(z\sqrt{2} - 3)$ to 2 per cent accuracy.

Table 2 gives values of z for various gauges of copper wire at 1Mc/s, the value of z for manganin being $1/\sqrt{(44/1{\cdot}7)} = 1/5{\cdot}1$ times the value for copper.

At frequency f the value is $\sqrt{f}/1\,000$ times the tabulated value.

The skin effect is not noticeable until z becomes equal to unity, i.e. $f = \rho/8\pi^2 a^2$. At this value of z the skin effect increases the resistance by something less than 1 per cent. Table 3 gives values of frequency at which skin effect is present for various gauges of copper and eureka, while Table 4 gives the largest permissible wire diameter in mils for a skin effect ratio of 1·01 up to 3Mc/s for advance or manganin and nichrome.

TABLE 1
Values of F (Z) against Z

Z	0	0·5	1·0	1·5	2·0	2·5	3·0	3·5
$F(Z)$	0	·0003	·0053	·0258	·0782	·1756	·3180	·4930

TABLE 2
Values of Z for Various Gauges of Copper Wire at 1Mc/s

S.W.G.	10	12	14	16	18	20	22	24	26	30	36	40
Z	35·0	28·5	22·0	17·5	13·1	9·7	7·7	6·0	4·9	3·4	2·07	1·31

TABLE 3
Frequency at which Skin Effect begins to be Appreciable

S.W.G.	20	24	28	30	32	34	36	38	40
COPPER (kc/s) ..	10·3	27·6	61	86	114	157	230	370	580
EUREKA (kc/s) ..	267	715	1 580	2 220	—	—	—	—	

TABLE 4
Largest Permissible Wire Diameter in Mils for Skin Effect Ratio of 1·01

FREQUENCY (kc/s)	NICHROME	ADVANCE MANGANIN
100	104·5	70·2
200	74·5	49·6
500	46·8	31·4
1 000	33·1	22·2
2 000	23·4	15·7
3 000	19·1	12·8

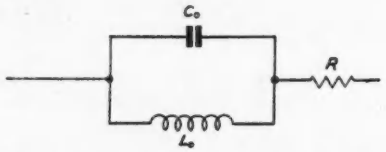


Fig. 1. Equivalent circuit of wirewound resistor

Measurements at radio frequencies are more difficult on account of residuals affecting measurement[3].

An approximation of the C_o and L_o in a resistance coil of R ohms is represented as shown in Fig. 1. The impedance for the inductance and capacitance combination is:

$$z = \frac{R + j\omega[L(1 - \omega^2CL) - CR^2]}{(1 + \omega^2CL)^2 + \omega^2C^2R^2}$$

L and C are small so that approximately:

$$R' \simeq R[1 + \omega^2C(2L - CR^2)]$$

and:

$$L' \simeq L - CR^2$$

The phase displacement between voltage and current flowing into the coil is:

$$\phi \simeq \tan^{-1} \cdot \frac{\omega(L - CR^2)}{R}$$

$$\simeq \tan^{-1} (\omega L'/R)$$

L' is the effective residual inductance.

If inductance preponderates over capacitance (i.e. $L > CR^2$) then L' is positive. If capacitance preponderates then CR^2 exceeds the inductance and L' is negative.

The time-constant T of the coil $= L/R - CR = L'/R$ which is positive or negative according as L is greater or less than CR^2 and is of the order of 10^{-7}sec or less in a well designed resistance coil.

The resistance will be pure if $L=CR^2$. More exactly, $C = \frac{L}{R^2 + \omega^2L^2}$ but generally ω^2L^2 is negligible compared with R^2. Thus by suitable spacing it is possible to balance the inductance and capacitance to get a reasonably pure resistance.

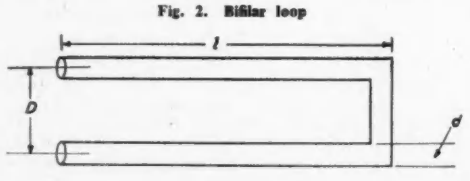
Design and measurement are wide subjects, some branches of which are not amenable to exact calculation and are best approached by trial methods and the help of experience.

Design depends very much on the frequency and it is unfortunately a fact that the resistance, capacitance and inductance of a resistor may vary with frequency.

Apart from skin and proximity effects, the inductance of a piece or coil of wire will decrease for these effects, but the effective inductance as measured by an a.c. bridge will rise because of the C_o, reach a maximum, diminish to zero and then the reactance becomes capacitive.

One of the oldest and simplest forms of winding a resistor is the bifilar method where the wire is folded back on itself at the middle point and the conductor so formed is wound on a cylindrical bobbin. The inductance of the coil will be small and reduced further by twisting the leads together before winding. Since the go and return leads lie close together, there is a considerable capacitance with the full potential difference between the terminals which will preponderate over inductance at high values of resistance as it has a comparative long length of fine wire. This method of winding is thus used more for lower value resistors.

Fig. 2. Bifilar loop



For d.c. work, the wire may be coiled or bunched indescriminately, but as will be appreciated, in a.c. circuits, the method of construction is important.

The impedance of a bifilar loop (Fig. 2) is that of a short-circuited transmission line which may be shown to be the impedance shunted by one-third of the shunt admittance, in this case the total C_o between the wires. In order to produce a pure resistance, L_o and C_o must be made very small or balanced against each other in the range of frequencies employed.

A popular method of winding is after Chaperon, made by winding with a single wire an even number of layers reversing the direction of winding of each layer. Sometimes the modified form of Wagner and Weitheimer is used where considerable control may be exercised over the time-constant of the coil by arranging the winding in a number of Chaperon sections connected in series. Various modified forms of this are used when manufactured under works conditions of mass production and fairly wide variations of time-constant result. Some of these are included in Table 5, which is an examination of some figures published by several leading manufacturers. They offer the conclusion that the precise values in any particular case depend on whether shielding is provided or not and the physical arrangement of the resistors etc.

TABLE 5
Time-Constants Resulting from Figures Published by Several Leading Manufacturers

RESISTANCE	TIME-CONSTANT	AVERAGE
0·1 ohm.	13 to 100×10-⁸ secs.	—
1·0 ,,	5 to 40×10-⁸ ,,	12×10-⁸ secs.
10 ,,	2 to 8×10-⁸ ,,	2×10-⁸ ,,
100 ,,	0.2 to 1×10-⁸ ,,	0·4×10-⁸ ,,
1 000 ,,	±5×10-⁸ ,,	—
10 000 ,,	±18×10-⁸ ,,	—

Reverting to Fig. 2, if the wires are length l diameter d, and D is the distance between centres then[4]:

$$L = 0{\cdot}004l \ (\log_h 2D/d - D/l + \mu\delta) \ \mu H$$

and the total capacitance between the wires is:

$$1{\cdot}11/2 \cosh^{-1} (D/d) \text{ pF.}$$

Also for a bifilar resistor the effective inductance can be shown to be approximately $L - \frac{1}{3}CR^2$ so that for some value of D, the expression $L - \frac{1}{3}CR^2$ can be made equal to zero, giving an approximately pure resistance.

A popular method is to wind one-half of the resistor in one direction and the other half at a suitable distance in the opposite direction.

The capacitance between layers may be varied by varying the distance between them which thus balances the inductance. A resistance coil cannot be wound so as to be entirely free of all self-inductance and self-capacitance, and

it thus becomes a question of careful design and construction to effect the best compromise.

In general, sub-dividing a given length of wire into n non-inductive sections will give a self-capacitance effect approximately $1/n^2$ as great as that obtained if the wire were arranged in one non-inductive winding.

Many methods described in text books for reducing

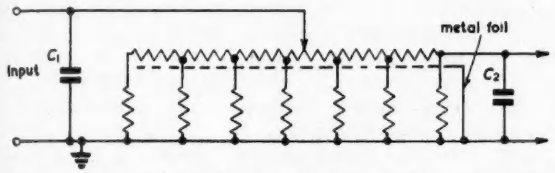


Fig. 3. Output attenuator of a signal generator showing circuit modifications to offset residual inductance

residuals are interesting and only practical for special applications such as the construction of standard components and instruments. What is of importance in industry is to produce as far as is possible a resistor that has as many desirable features as possible and yet can be manufactured under mass production conditions if necessary, at a low cost.

The useful frequency range of a wirewound resistor is obviously determined by the degree of residuals that can be tolerated and it is seldom that such resistors of whatever construction are used much above 25Mc/s except perhaps in special cases and then they are usually low values of necessity, as corrections for residuals begin to become unwieldy, such that actual circuit modifications are called for to offset them as exemplified in the schematic diagram of the variable r.f. attenuator in Fig. 3. The elements of the latter, although perhaps non-inductively wound, may still be slightly inductive predominant say, requiring small capacitances C_1 and C_2 in the input and output circuits respectively, together with a distributed capacitance provided by a strip of metallic foil mounted adjacent to the variable slide arm element to lift any resonant rise of voltage beyond the frequency range contemplated.

Conclusion

Resistors employing many of the features in these notes are used in electronic equipment where accuracy is the keynote, and, without wishing to labour the point, may it be stressed that it is such careful attention to detail in the construction, testing and ageing processes that enables this component to maintain its stability with time and retain the initial high accuracy to which it was adjusted.

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An Impact Microphone for Counting and Batching

The Sargrove impact microphone is designed to solve the problem of counting at high speed light weight small parts of diverse shapes from ¼in up to 2in dimensions which by their nature (such as perforated cylinders or wrapped sweets) cannot be conveniently catered for by photo optical perception. It is particularly suitable where objects of different sizes have to be dealt with by the same counting apparatus.

Where the objects to be counted and dispensed cannot be presented in a regular flow and the succession of objects may be very close together at times, the impact microphone is especially suitable due to its very high perception speed also the feature of design, whereby the microphone shell, on which the falling objects strike, is also the batching gate, thus eliminating time delay to a minimum in the exact discrimination between the end of one batch and the start of the next.

IMPACT MICROPHONE HEAD

This consists of a miniature pressure type moving-coil microphone assembly fully sealed against dust or moisture. The microphone is coupled acoustically to a pneumatic chamber calculated to resonate with the impact shell which forms the top end of the assembly in a disk some 2½ in. in diameter.

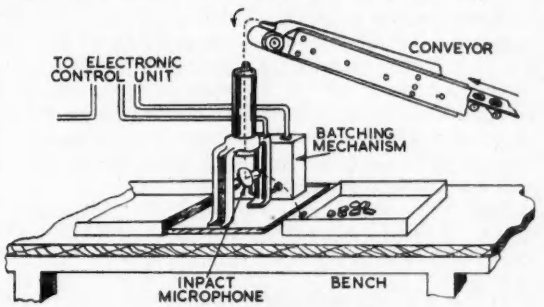
The whole assembly is poised on a central axle shaft to which is coupled a quick return spring loaded twin solenoid assembly, arranged to rotate the microphone through 90° at very high acceleration so that it is held at 45° to the vertical and can discharge the falling objects in the horizontal plane to right or left hand. When the number set on the electronic unit has been counted, instantly the microphone is rotated into the alternative position carrying with it the next object to fall (if this should be following on the heels of the last object) counting this object at the same time as number one in the next batch.

PROCESS OF COUNTING

A falling object strikes the sloping disk of the microphone shell and bounces off into its appropriate batch chute, but in so doing it triggers off the natural resonance of the microphone by compressing instantaneously the pneumatic chamber which in turn compresses the microphone diaphragm generating a series of sonic middle frequency electrical pulses.

The resonance is rapidly damped by the acoustic resistance in the course of a few cycles, but the electronic circuits associated with the microphone circuit accepts only the initial part of the steep slope of the first pulse, shaping this to adequate proportions to suit the electronic counter batcher unit, thus variations in striking force do not affect the pulse amplitude.

Allowing adequate time for the vibrations to die down, the electronic unit becomes unmuted and ready for the next



The impact microphone assembly

impact. A total time of approximately one hundredth of a second is occupied by this process, thus impacts can be handled comfortably at 30 per second, or 2 000 per minute counting rate.

Each properly shaped and amplified pulse is fed into an electronic counter batcher capable of counting at 200 per second which adds these pulses until the total number preset on the controls has been reached, when it instantaneously resets to zero and operates the batching mechanism simultaneously, which swings the microphone over to be in its position to deflect the next object into the alternative batch channel.

The Matrix Approach to Filters and Transmission Lines

By M. E. Fisher*

(Part 2)

Canonical Form of the Filter Equations

For a finite line of similar quadripoles it has been shown that the currents and voltages at the input and the n^{th} terminals are related by the matrix equations:

$$\mathbf{x}_o = \mathbf{A}^n\mathbf{x}_n \quad \mathbf{x}_n = \mathbf{A}^{-n}\mathbf{x}_o \quad \ldots\ldots\ldots\ldots \quad (58)$$

Now $\mathbf{A}^n$ is a square matrix which can be found by multiplying $\mathbf{A}$ by itself n times in succession. Although not difficult, this method is tedious and does not give a general result for all n. Such a general expression will be derived which avoids repeated matrix multiplication.

First of all notice that if $\mathbf{x}_n$ happens to be an eigen-vector of the matrix $\mathbf{A}$, say $\mathbf{w}$, then the effect of the matrix multiplication is merely to multiply $\mathbf{x}_n$ or $\mathbf{w}$ by ξ where ξ is the appropriate eigen-value. In symbols:

$$\mathbf{x}_o = \mathbf{A}^n\mathbf{x}_n = \mathbf{A}^n\mathbf{w} = \xi^n\mathbf{w} \quad \ldots\ldots\ldots \quad (59)$$

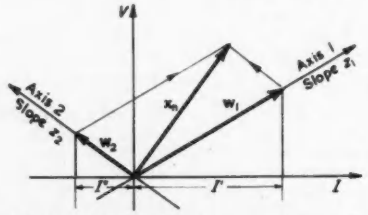


Fig. 11. Illustrating the decomposition of a general vector $\mathbf{x}_n$ into the sum of two eigen-vectors

In general, though, $\mathbf{x}_n$ will not be an eigen-vector of $\mathbf{A}$. For example if the line is terminated at the n^{th} pair of terminals with an impedance Z different from the iterative impedance, we have $V_n = ZI_n$ which does not fulfil the condition for the slope of the eigen-vector, viz., $V_n = \zeta_1 I_n$. In such a case we can use the device of vector resolution. $\mathbf{x}_n$ can be interpreted as a vector not lying along the axes of the matrix (Fig. 11). Then it can be decomposed into the sum of two vectors, each being along one of the axes and hence being eigen-vectors.

Thus:

$$\mathbf{x}_n = \mathbf{w}_1 + \mathbf{w}_2 = \begin{bmatrix} z_1 I' \\ I' \end{bmatrix} + \begin{bmatrix} z_2 I'' \\ I'' \end{bmatrix} \ldots\ldots \quad (60)$$

z_1 and z_2 are the characteristic impedances measuring the slope of the eigen-values (equation (45)). We are now in a position to simplify equation (58) into a form not requiring matrix multiplication but only needing multiplication by the n^{th} powers of the eigen-values.

$$\mathbf{x}_o = \mathbf{A}^n\mathbf{x}_n = \mathbf{A}^n(\mathbf{w}_1+\mathbf{w}_2) = \mathbf{A}^n\mathbf{w}_1 + \mathbf{A}^n\mathbf{w}_2 = \xi_1{}^n\mathbf{w}_1 + \xi_2{}^n\mathbf{w}_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (61)$$

Thus by equation (56) and equation (60):

$$\mathbf{x}_o = \xi_1{}^n\begin{bmatrix} \zeta_1 I' \\ I' \end{bmatrix} + \xi_2{}^n\begin{bmatrix} -\zeta_2 I'' \\ I'' \end{bmatrix} \ldots\ldots\ldots \quad (62)$$

This simplification is analogous to the method where in elementary mechanics, forces are split into their components which are added together and then recombined to give the resultant force rather than use the more difficult method of adding forces by the triangle law.

Equation (60) can be rewritten using the iterative or surge impedances ζ_1 and ζ_2 as:

$$\begin{aligned} V_n &= \zeta_1 I' - \zeta_2 I'' \\ I_n &= I' + I'' \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots \quad (63)$$

Solving these for I' and I'', and substituting into equation (62) gives:

$$\mathbf{x}_o = \begin{bmatrix} V_o \\ I_o \end{bmatrix} = \frac{1}{\zeta_1+\zeta_2}\begin{bmatrix} \zeta_1\xi_1{}^n + \zeta_2\xi_2{}^n & \zeta_1\zeta_2(\xi_1{}^n - \xi_2{}^n) \\ \xi_1{}^n - \xi_2{}^n & \zeta_2\xi_1{}^n + \zeta_1\xi_2{}^n \end{bmatrix}\begin{bmatrix} V_n \\ I_n \end{bmatrix} \quad \ldots\ldots\ldots\ldots \quad (64)$$

This equation gives $\mathbf{x}_o$ directly in terms of $\mathbf{x}_n$ by multiplication by a single matrix whose coefficients are functions of n, ξ_1, ξ_2 and ζ_1, ζ_2 only.

If γ is the propagation constant $e^{\gamma} = \xi_1$ and $e^{-\gamma} = \xi_2$ and the matrix in equation (64) can be simplified. Furthermore the equation can be inverted to give V_n and I_n in terms of input voltages and currents. The matrix for this is:

$$\mathbf{A}^{-n} = \frac{1}{\zeta_1+\zeta_2}\begin{bmatrix} \zeta_1 e^{n\gamma} + \zeta_2 e^{-n\gamma} & -2\zeta_1\zeta_2 \sinh n\gamma \\ -2\sinh n\gamma & \zeta_2 e^{n\gamma} + \zeta_1 e^{-n\gamma} \end{bmatrix} \quad (65)$$

This is known as the *canonical form* of the matrix for the line of n quadripoles.

If the quadripoles are reversible there is a further simplification since $\zeta_1 = \zeta_2 = \zeta$

$$\mathbf{A}^{-n} = \begin{bmatrix} \cosh n\gamma & -\zeta\sinh n\gamma \\ -\zeta^{-1}\sinh n\gamma & \cosh n\gamma \end{bmatrix} \ldots\ldots\ldots \quad (66)$$

This matrix is important since it generalizes to the case of a continuous line, which is, of course, reversible.

The analysis has thus carried us to a stage where we can directly calculate the voltages and currents at any pair of terminals if we know the input conditions for a line.

Example

To illustrate this, consider a hypothetical filter fed by an a.c. generator delivering 10V peak with an internal impedance of $R = 50\Omega$. Suppose that the filter sections are reversible and that at the frequency in question the iterative impedance is 100Ω and the propagation constant is $\gamma = j\pi/2$, i.e. the frequency is in a pass-band of the filter. Suppose also that the filter is correctly terminated with the iterative impedance ζ. The current in the generator, I_o, is given by Ohm's law as:

$$I_o = \frac{V_o}{R+\zeta} = 10/150 = 1/15 \text{ amps} \quad \ldots\ldots \quad (67)$$

Now: $\mathbf{x}_n = \mathbf{A}^{-n}\mathbf{x}_o$

and: $\operatorname{cosh} j\theta = \cos\theta, \ \sinh j\theta = j\sin\theta \quad \ldots\ldots \quad (68)$

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so that using equation (66) for $\mathbf{A}^{-n}$:

$$V_n = V_0 \cos \tfrac{1}{2}n\pi - \zeta I_0 \mathrm{j} \sin \tfrac{1}{2}n\pi = 10 \cos \tfrac{1}{2}n\pi - \mathrm{j}\, 20/3 \sin \tfrac{1}{2}n\pi \quad \ldots\ldots\ldots\ldots (69)$$

$$I_n = -V_0 \zeta^{-1} \mathrm{j} \sin \tfrac{1}{2}n\pi + I_0 \cos \tfrac{1}{2}n\pi = -\mathrm{j}\, 1/10 \sin \tfrac{1}{2}n\pi + 1/15 \cos \tfrac{1}{2}n\pi$$

Thus for example at the third pair of terminals the peak voltage is $7\frac{1}{2}$V and the peak current 1/10A the phase of both being 90° in advance of the generator, while at the fourth pair of terminals the peak values are 10V and 1/15A and both voltage and current are in phase with the generator.

Equations for a Continuous Line

The equations governing the voltage and current distribution on continuous lines are usually derived by he use of differential equation theory. We will avoid this method by generalizing the results of the preceding paragraphs to the continuous case. We regard the continuous line as a series of indefinitely small similar quadripoles connected in cascade.

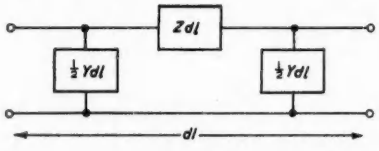


Fig. 12. Infinitesimal quadripole of π-type

The voltage and current will now be a function of l the length along the line. However, we can write:

$$\mathbf{x}(l) = \begin{bmatrix} V(l) \\ I(l) \end{bmatrix} = \mathbf{A}^{-1}(l) \begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \mathbf{A}^{-1}(l)\, \mathbf{x}_0 \quad \ldots\ldots (70)$$

by analogy with equation (58).

The matrix $\mathbf{A}^{-1}(l)$ will be a matrix with elements depending on l. The object is to evaluate this matrix in terms of the series impedance Z per unit length of the line and the parallel admittance Y per unit length.

Suppose that the line is made up of a series of small π-type reversible quadripoles of length dl. (See Fig. 12; there is no loss in generality through including all the series impedance in one arm, since the matrix is the same however the impedance is split between the two arms.)

The matrix for this quadripole is:

$$\begin{bmatrix} 1 + \tfrac{1}{2}YZ\,dl^2 & Zdl \\ (1 + \tfrac{1}{4}YZl^2)Ydl & 1 + \tfrac{1}{2}YZdl^2 \end{bmatrix} \quad \ldots\ldots (71)$$

Since the quadripole is reversible, the two iterative impedances will be equal: thus by equation (57):

$$\zeta = \sqrt{(a_{12}/a_{21})} = \left[\frac{Z}{Y(1 + \tfrac{1}{4}YZdl^2)}\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots (72)$$

In the limit as the length of the elementary quadripoles becomes vanishingly small, i.e. as $dl \to 0$, this gives the well-known expression for the surge impedance of a continuous line:

$$\zeta = \sqrt{(Z/Y)} \quad \ldots\ldots\ldots\ldots\ldots (73)$$

In a practical case with negligible resistance and leakance the surge impedance is $\rho = \{L/C\}^{\frac{1}{2}}$ where L and C are the inductance and capacitance per unit length. This illustrates the familiar fact that the surge impedance, ρ, of a lossless line is purely resistive and is frequency independent.

The trace of the matrix equation (71) is:

$$a_0 = 2 + YZdl^2 \quad \ldots\ldots\ldots\ldots\ldots (74)$$

we relate this to the propagation constant γ for the quadripole by equation (36):

$$a_0 = \xi + 1/\xi = e^{\gamma} + e^{-\gamma} = 2 \cosh \gamma \quad \ldots\ldots (75)$$

Now the propagation constant for an overall quadripole formed of n-similar quadripoles in cascade is just n times the propagation constant for the individual quadripoles. (This follows from the canonical form of the $\mathbf{A}^n$ matrix equation (65)). So that if the propagation constant of a unit length of continuous line is Γ the propagation constant for one of the elementary quadripoles is:

$$\gamma = \Gamma dl \quad \ldots\ldots\ldots\ldots\ldots (76)$$

Using this result and equating the two expressions for a_0 (74), (75) we obtain, after expanding $\cosh \Gamma dl$ in a power series:

$$YZ = \Gamma^2 + 1/12\, \Gamma^4 dl^2 + \ldots\ldots$$

which in the limit as $dl \to 0$ gives:

$$\Gamma = \sqrt{YZ} \quad \ldots\ldots\ldots\ldots\ldots (77)$$

In the case discussed above of negligible resistance and leakance $\Gamma = \{-\omega^2 LC\}^{\frac{1}{2}}$ and is thus purely imaginary so that all frequencies are transmitted down a lossless continuous line without attenuation. The speed of the waves is obtained from equation (34). For this case it gives the well-known result:

$$c = 1/\sqrt{LC} \quad \ldots\ldots\ldots\ldots (78)$$

since $\beta = \Gamma/\mathrm{j} = \omega\sqrt{LC}$; the wavelength being:

$$\lambda = 2\pi/\beta = 2\pi/\omega\sqrt{LC} \quad \ldots\ldots\ldots (79)$$

We are now in a position to generalize the reversible $\mathbf{A}^{-n}$ matrix of equation (66), to the matrix $\mathbf{A}^{-1}(l)$ matrix for the continuous line. By equation (76) above $n\gamma = n\Gamma dl = \Gamma(ndl)$ where Γ is the propagation constant for the continuous line. n is the number of elementary quadripoles forming a given section of the line so that $ndl = l$, the length of the section. Thus for a continuous line we have the matrix:

$$\mathbf{A}^{-1}(l) = \begin{bmatrix} \cosh \Gamma l & -\zeta \sinh \Gamma l \\ -\zeta^{-1} \sinh \Gamma l & \cosh \Gamma l \end{bmatrix} \quad \ldots\ldots\ldots (80)$$

so that at a distance l from the beginning of the line:

$$\begin{bmatrix} V(l) \\ I(l) \end{bmatrix} = \mathbf{A}^{-1}(l) \begin{bmatrix} V_0 \\ I_0 \end{bmatrix} \quad \ldots\ldots\ldots (81)$$

In the case of negligible resistance and leakance $\Gamma = \mathrm{j}\beta = 2\pi\mathrm{j}/\lambda$ and the matrix becomes:

$$\mathbf{A}^{-1}(l) = \begin{bmatrix} \cos 2\pi l/\lambda & -\rho \mathrm{j} \sin 2\pi l/\lambda \\ -\rho^{-1} \mathrm{j} \sin 2\pi l/\lambda & \cos 2\pi l/\lambda \end{bmatrix} \quad \ldots\ldots (82)$$

Here the surge impedance $\zeta = \rho$ is independent of frequency by equation (73), while the wavelength is inversely proportional to frequency by equation (79). In other words the velocity is constant.

Equations (80) and (81) together with (73) and (77) are the basic equations for a continuous line. From them the complete theory of lines can be developed directly.

The Loaded Line

In a practical transmission line there will always be some attenuation present due to the finite resistance of the line

which cannot economically be reduced below certain limits. Furthermore, the presence of this resistance makes the velocity of propagation depend on frequency and so leads to distortion of the signal. This effect can be examined by taking the series impedance per unit length to be $Z = R + j\omega L$ and the parallel admittance to be $Y = j\omega C$. (In most practical cases the leakance can safely be disregarded.) The propagation constant is then given by equation (77).

$$\Gamma = \alpha + j\beta = \sqrt{YZ} = \sqrt{j\omega C(R + j\omega L)} = j\omega\sqrt{LC}(1 + R/j\omega L) \quad \ldots\ldots\ldots\ldots (83)$$

When R is small we can expand the factor under the root sign by the binomial theorem whence comparing real and imaginary parts

$$\alpha = \tfrac{1}{2}R\sqrt{(C/L)} \quad \beta = (\omega\sqrt{LC}).\left\{1 + R^2/8\omega^2L^2\right\} \ldots (84)$$

The velocity of propagation is given by:

$$c = \beta/\omega = (\sqrt{LC}).\left\{1 + R^2/8\omega^2LC\right\} \ldots\ldots (85)$$

which shows how the velocity depends on the frequency. However if L the inductance per unit length is made large, α, the attenuation, is reduced and the velocity of propagation becomes less dependent on frequency. The inductance per unit length of a transmission line is difficult to increase by direct methods, so, as is familiar to all electrical

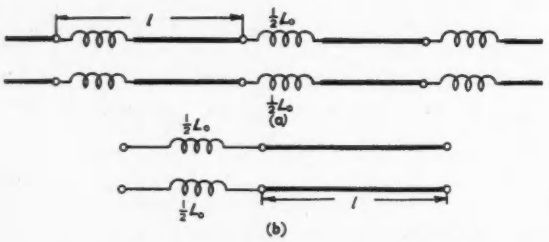


Fig. 13(a). Loaded transmission line as a chain of similar quadripoles. (b) Structure of a single quadripole forming the transmission line

engineers, this problem is solved in practice by loading the transmission line with coils at regular intervals. Of course, this is not exactly equivalent to increasing the inductance per unit length, since it destroys the continuity of the line and introduces a periodic structure determined by the coil spacing. Because of this the line behaves as a filter cutting out certain frequencies.

To illustrate the power of matrix methods this problem will be discussed on the basis of the foregoing theory. Fig. 13(a) shows a loaded transmission line which can be regarded as a chain of similar quadripoles, each quadripole consisting of a length of continuous line adjoined to a total series inductance L_0.

Fig. 13(b) shows how each of these similar quadripoles can be regarded as two quadripoles in cascade. One of these is formed by the inductors and has a matrix:

$$\mathbf{B} = \begin{bmatrix} 1 & j\omega L_0 \\ 0 & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots (86)$$

The other quadripole is formed by a length l of the continuous transmission line, where l is the spacing distance of the loading coils. The direct matrix for this is given by equation (80):

$$\mathbf{C} = \begin{bmatrix} \cosh\gamma l & \zeta\sinh\gamma l \\ \zeta^{-1}\sinh\gamma l & \cosh\gamma l \end{bmatrix} \ldots\ldots\ldots\ldots (87)$$

where γ is the propagation constant per unit length of the unloaded line.

The matrix for the complete quadripoles which go to form the transmission line is given by the matrix product:

$$\mathbf{A} = \mathbf{BC} = \begin{bmatrix} \cosh\gamma l + j\omega L_0\zeta^{-1}\sinh\gamma l & \zeta\sinh\gamma l + j\omega L_0\cosh\gamma l \\ \zeta^{-1}\sinh\gamma l & \cosh\gamma l \end{bmatrix}$$

This matrix completely determines the behaviour of the loaded transmission line. For example the trace of this matrix is:

$$a_0 = 2\cosh\gamma l + j\omega L_0\zeta^{-1}\sinh\gamma l = 2\cosh\Gamma l \ldots\ldots (88)$$

where Γ is the effective propagation constant per unit length for the loaded line. This equation determines Γ and hence the attenuation and velocity of propagation on the loaded line.

The pass-band structure of the loaded line can be obtained graphically from a_0 as for simple filters. For this purpose we ignore the resistance so that γ becomes purely imaginary. The trace then is:

$$a_0 = 2\cos\omega l\sqrt{LC} - \omega L_0\zeta^{-1}\sin\omega l\sqrt{LC} \ldots\ldots (89)$$

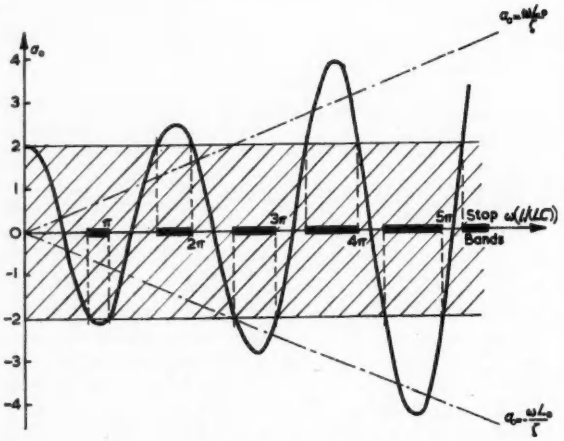


Fig. 14. Graph of a_0 against ω for a loaded transmission line

Fig. 14 shows a graph of a_0 against ω. As before the ranges of ω for which this curve leaves the region $-2 \leqslant a_0 \leqslant 2$ give the stop-bands. These stop-bands are marked along the ω axis. The first one occurs at the region given by:

$$\omega l\sqrt{LC} = \pi \quad \ldots\ldots\ldots\ldots\ldots (90)$$

This corresponds to $l = \lambda/2$, that is to a spacing of the coils at distances of one-half wavelength. Thus in a practical case there must be a number of coils to the wavelength of the highest frequency which the line is required to transmit. At higher frequencies the stop-bands grow progressively broader, although they never coalesce to wipe out the pass-bands. The rate at which the stop-bands broaden is determined by the ratio of the load inductance L_0 to the surge impedance ζ of the continuous line.

Input Impedance to a Quadripole

A commonly occurring type of network is illustrated in Fig. 15 which shows a quadripole with matrix **A** loaded with an impedance Z connected across its output terminals. The input impedance to the network, Z_0, is given by the

ratio of the input voltage V_0, to input current I_0. The relations are:

$$V_0 = Z_0 I_0 \quad V_1 = Z I_1 \quad \ldots\ldots\ldots\ldots \quad (91)$$

and:

$$\begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_1 \end{bmatrix}$$

Writing out the two equations corresponding to the matrix equation and dividing one by the other gives:

$$Z_0 = \frac{a_{11}Z + a_{12}}{a_{21}Z + a_{22}} \quad \ldots\ldots\ldots\ldots \quad (92)$$

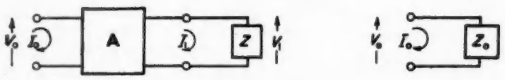
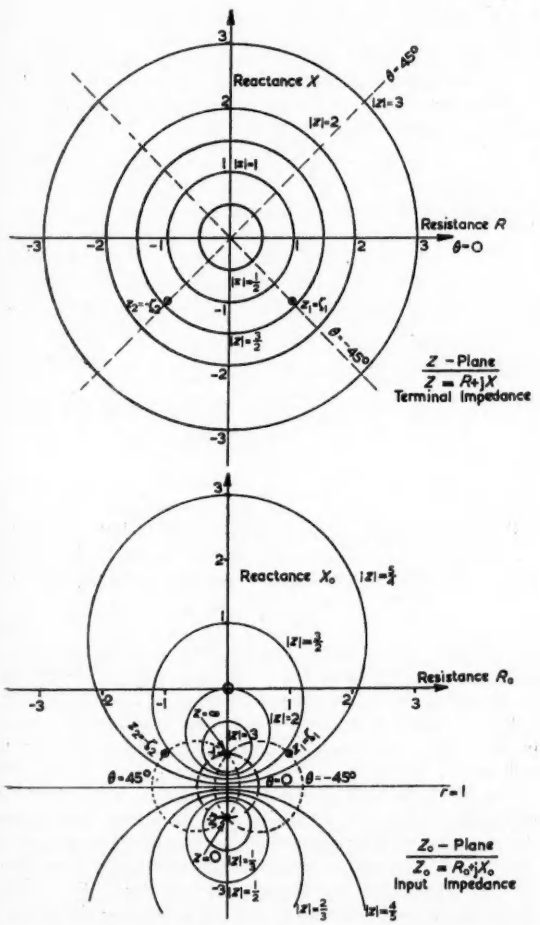


Fig. 15. Loaded quadripole and its input impedance



(● indicates the values of Z which transform into themselves ie. ζ_1 and $-\zeta_0$)

Fig. 16. Z and Z_0 plane for the transformation $Z_0 = \frac{Z+2j}{jZ-1}$

The values of the complex coefficients a_{ij}, depend on the nature of the particular quadripole, which may be formed from a length of transmission line, a chain of quadripoles or other combinations. However, the form of the functional relationship between Z_0 and Z remains unchanged. Following Pipes[5] and other authors[6] we may regard the quadripole as an *impedance transformer*, the particular nature of the transformation being determined by the matrix of the quadripole. The output impedance Z is transformed and appears at the input terminals as another impedance Z_0. Conversely if equation (92) is solved for Z in terms of the input impedance Z_0 a similar type of equation is obtained showing that for a given quadripole only one value of terminal impedance Z will give a required input impedance Z_0.

Transformations of Z to Z_0 by equations of the type of equation (92) are called *Bilinear* or *Homographic* transformations and are well known in mathematics.

They have a number of properties of importance to our theory.

(i) The bilinear transformation is the most general transformation that transforms a unique value of Z into a unique value of Z_0 and vice-versa.

(ii) The bilinear transformation transforms the complete Z-plane into the complete Z_0-plane. By the term Z-plane is meant the plane determined by the axes of the resistive and the reactive components of Z, so that any given value of the impedance Z is represented by a point in this plane (Fig. 16). This property of transforming the complete Z-plane into the complete Z_0-plane shows that any value whatsoever of input impedance can be realized by some suitable output impedance and vice-versa.

(iii) Finally, the bilinear transformation transforms circles in the Z-plane into circles in the Z_0-plane. In this case straight lines are regarded as degenerate circles with infinite radius. This property is illustrated in Fig. 16 for the particular transformation.

$$Z_0 = \frac{Z + 2j}{jZ - 1} \text{ with matrix } \mathbf{A} = \begin{bmatrix} 1 & 2j \\ j & -1 \end{bmatrix}$$

and $|\mathbf{A}| = 1$

Here the circle $|Z| = 1$ is transformed into the line $X_0 = -3/2$ while the radial lines in the Z-plane representing a constant ratio of X to R are transformed into circles in Z_0-plane (shown dotted) passing through the points $Z_0 = -j$ and $Z_0 = -2j$. These two points correspond to $Z = \infty$ and $Z = 0$, i.e. to open- and short-circuited conditions, respectively.

This property of the bilinear transformation with respect to circles accounts for the large number of circle diagrams and circular calculators that occur in the theory of impedance transformation and matching[5,6].

Variation of Input Impedance to a Line

If as in many practical cases the quadripole or *impedance transformer* consists of a series of n similar quadripoles in cascade, the coefficients of the overall matrix can be obtained from equation (65). Then the expression (equation (92)) for the input impedance to the chain becomes:

$$Z_0 = \frac{Z(\zeta_1 e^{n\gamma} + \zeta_2 e^{-n\gamma}) + 2\zeta_1\zeta_2 \sinh n\gamma}{2Z \sinh n\gamma + \zeta_2 e^{n\gamma} + \zeta_1 e^{-n\gamma}} \quad \ldots\ldots \quad (93)$$

where ζ_1 and ζ_2 are the iterative impedances in the forward and reverse directions and $\gamma = \alpha + j\beta$ is the propagation constant for a single quadripole of the chain.

Suppose the chain is terminated with the forward iterative impedance, i.e. $Z = \zeta_1$, then the input impedance is $Z_o = \zeta_1$, by equation (93). In other words the forward iterative impedance is transformed into itself. (See Fig. 16 where $z_1 = \zeta_1$ and $z_2 = -\zeta_2$ are shown in the Z and Z_o-planes). This demonstrates the well-known fact that the impedance of a finite chain, correctly terminated with the iterative impedance, is the same as of the corresponding infinite chain.

If the chain is not terminated with the iterative impedance ζ_1 there are two cases to consider depending on whether the line is operating in a pass-band or a stop-band. If the line is attenuating the waves so that γ the propagation constant has a real part, we may neglect $e^{-n\gamma}$ provided comparison with $e^{n\gamma}$ provided the chain is long (n large). The expression for input impedance then reduces to:

$$Z_o = \frac{Z\zeta_1 e^{n\gamma} + \zeta_1\zeta_2 e^{n\gamma}}{Ze^{n\gamma} + \zeta_2 e^{n\gamma}} = \zeta_1 \quad \ldots\ldots\ldots (94)$$

Thus the input impedance to a long line which is attenuating is equal to the iterative impedance and effectively independent of the terminal impedance.

In a pass-band where the attenuation is negligible γ becomes purely imaginary and equal to $j\beta$. In this case the input impedance is:

$$Z_o = \frac{Z(\zeta_1+\zeta_2)\cos n\beta + j\{Z(\zeta_1-\zeta_2)+2\zeta_1\zeta_2\}\sin n\beta}{(\zeta_1+\zeta_2)\cos n\beta + j\{(\zeta_2-\zeta_1)+2Z\}\sin n\beta} \quad (95)$$

and the input impedance is critically dependent on the length of the quadripole chain.

In particular if:

$$n\beta = m\pi, \text{ i.e. } n = m\lambda/2 \quad \ldots\ldots\ldots (96)$$

where m is an integer, then $Z_o = Z$.

Thus if the length of the line fulfils the condition of equation (96), i.e. if it is an integral number of half wavelengths long, then the input impedance is the same as the terminal impedance. The chain of quadripoles acts as a one-to-one transformer.

Equation (95) generalizes directly to the continuous case by putting $\zeta = \zeta_1 = \zeta_2$ and replacing $n\beta$ by $2\pi l/\lambda$, where l is the length of continuous transmission line between the input and output terminals.

Then:

$$z_o = \frac{z + j\tan 2\pi l/\lambda}{1 + jz\tan 2\pi l/\lambda} \quad \ldots\ldots\ldots (97)$$

where z_o and z are the so-called *normalized* input and terminal impedances given by:

$$z_o = Z_o/\zeta \text{ and } z = Z/\zeta \quad \ldots\ldots\ldots (98)$$

This is the general equation behind the usual theory of matching line impedances. It is discussed at length in standard works[6]. For example, we can consider the case of open-circuited output terminals, i.e., $Z = \infty$.

In this case:

$$Z_o = j\zeta\cot 2\pi l/\lambda \quad \ldots\ldots\ldots (99)$$

Since ζ is real corresponding to a resistive surge impedance the input impedance is generally reactive. Furthermore if the line is an odd number of quarter-wavelengths long we have the condition of resonance, i.e.:

$$l = (2m + 1)\lambda/4 \text{ so that } Z_o = 0 \quad \ldots\ldots (100)$$

Conversely if the line is an integral number of half-wavelengths long we have the condition of anti-resonance, that is infinite input impedance.

$$l = m\lambda/2 \text{ and } Z_o = \infty \quad \ldots\ldots\ldots (101)$$

Reflexion by the Terminal Impedance

It is a well-known result that a wave of voltage and current travelling down a transmission line or a chain of quadripoles is reflected at the terminal impedance unless this is equal to the forward surge or iterative impedance. The reflexion coefficient for a given termination can be defined as the complex ratio of incident voltage to reflected voltage across the terminal impedance. An alternative definition is in terms of the ratio of the forward-going incident current to reflected current taken in reverse sense. These reflexion coefficients can be evaluated on the basis of the vector interpretation if we remember that a forward-going or incident wave is represented by an eigen-vector $\mathbf{w}_1$ with ratio $z_1 = \zeta_1$ between its components and a reflected or reverse-going wave by an eigen vector $\mathbf{w}_2$ with ratio $z_2 = -\zeta_2$ (equations (45) and (46)). Then if the subscript n refers to total voltages and currents at the output terminals and the subscripts i and r to incident and reflected components we have, for terminal impedance Z:

$$\begin{aligned} V_n &= V_i + V_r \\ I_n &= I_i + I_r \end{aligned} \quad \ldots\ldots\ldots (102)$$

and:

$$V_n = ZI_n \quad V_i = \zeta_1 I_i \quad V_r = -\zeta_2 I_r \quad \ldots\ldots (103)$$

Eliminating I_i, I_r and I_n and then V_n we obtain V_r/V_i which is t the voltage reflexion coefficient at the output:

$$t = \zeta_2/\zeta_1 \cdot \frac{Z - \zeta_1}{Z + \zeta_2} \quad \ldots\ldots\ldots (104)$$

Similarly the current reflexion coefficient at the output is:

$$\tau = \frac{Z - \zeta_1}{Z + \zeta_2} \quad \ldots\ldots\ldots (105)$$

If Z_s is the internal impedance of the voltage generator supplying the input terminals we can similarly define two input reflexion coefficients for voltage and current, viz:

$$s = \zeta_1/\zeta_2 \cdot \frac{Z_s - \zeta_2}{Z_s + \zeta_1} \qquad \sigma = \frac{Z_s - \zeta}{Z_s + \zeta_1} \quad . (106)$$

If in equations (104) and (105) the terminal impedance Z is equal to ζ_1 the forward iterative impedance, the reflexion coefficients for both current and voltage vanish, proving the fact already referred to that there is no reflexion from a matched termination of the line. The vector interpretation of this is as follows. A certain value of terminal impedance fixes the ratio of V_n to I_n and hence the direction of the vector representing voltage and current $\mathbf{x}_n$. This vector can be resolved into a sum of two eigen-vectors $\mathbf{w}_1$ and $\mathbf{w}_2$ as is done in equation (102). These eigen-vectors represent pure waves travelling in the forward and reverse directions respectively. Now if $\mathbf{x}_n$ lies in the direction of the first axis of the matrix $\mathbf{A}$ of the quadripoles it can be represented as just a single eigen-vector $\mathbf{w}_1$ for a forward travelling wave, since $\mathbf{w}_1$ also lies in the axis (Fig. 11). In this case there is no reflected wave. The condition of same direction for $\mathbf{x}_n$ and the first axis of the $\mathbf{A}$ matrix is just that of equality of Z and ζ_1 which represent the slopes of the vector and the axis respectively.

In the case of a reversible chain of quadripoles or a con-

tinuous line the expressions for the reflexion coefficients simplify to the well-known form. In particular the distinction between voltage and current reflexion coefficients disappears.

$$s = \sigma = \frac{Z_s - \zeta}{Z_s + \zeta} \qquad t = \tau = \frac{Z - \zeta}{Z + \zeta} \quad \ldots\ldots (107)$$

Standing Waves

The concepts of reflexion coefficient enable us to solve one important problem tackled by the usual theory of lines; that is, what is the voltage distribution on a line fed by a voltage generator of internal impedance Z_s and electromotive force E, terminated by an impedance Z? The situation is shown in Fig. 17 where the internal impedance Z_s of the generator is regarded as forming an additional quadripole connected between the e.m.f. of the generator and the chain of n similar quadripoles. The problem is to find an expression for the voltage and current, V_l and I_l at the l^{th} pair of terminals in terms of the e.m.f., E of the generator, the coefficients of the **A** matrix specifying the quadripoles, or rather the propagation constant γ and

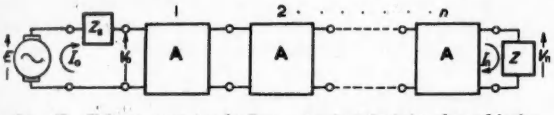


Fig. 17. Voltage generator feeding a terminated chain of quadripoles

the iterative impedances ζ_1 and ζ_2 for the quadripoles, and finally in terms of the impedances Z_s and Z.

We must start with the basic matrix equation for a chain of quadripoles:

$$\mathbf{x}_0 = \begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \mathbf{A}^l \begin{bmatrix} V_l \\ I_l \end{bmatrix} \quad \ldots\ldots\ldots (108)$$

When $l = n$ we have the relation $V_n = ZI_n$ so that:

$$\begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \mathbf{A}^n \begin{bmatrix} V_n \\ I_n \end{bmatrix} = \mathbf{A}^n \begin{bmatrix} 1 \\ 1/Z \end{bmatrix} V_n \quad \ldots\ldots (109)$$

Equation (108) can be inverted to give an expression for the $\mathbf{x}_l$ matrix in terms of $\mathbf{x}_0$ and hence by equation (109) in terms of V_n.

$$\begin{bmatrix} V_l \\ I_l \end{bmatrix} = \mathbf{A}^l \begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \mathbf{A}^{n-l} \begin{bmatrix} 1 \\ 1/Z \end{bmatrix} V_n \quad \ldots\ldots (110)$$

Our problem can now be solved directly if we can find V_n in terms of E the generator e.m.f. To do this we consider the quadripole formed by the generator impedance Z_s. This gives:

$$\begin{bmatrix} E \\ I_0 \end{bmatrix} = \begin{bmatrix} 1 & Z_s \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_0 \\ I_0 \end{bmatrix} = \begin{bmatrix} 1 & Z_s \\ 0 & 1 \end{bmatrix} \mathbf{A}^n \begin{bmatrix} 1 \\ 1/Z \end{bmatrix} V_n \quad (111)$$

When the matrix multiplication of the last part of this equation is carried out we obtain two equations. One gives E in terms of V_n and hence V_n in terms of E which is required, while the other gives I_0 in terms of V_n and is already contained in equation (109). The first of these equations is:

$$E = \left\{ a_{11}^{(n)} + a_{22}^{(n)} Z_s/Z + a_{21}^{(n)} Z_s + a_{12}^{(n)}/Z \right\} V_n \quad (112)$$

The coefficients $a_{11}^{(n)}$ are the coefficients of the matrix $\mathbf{A}^n$. These coefficients are given by the previous work, equation (65), in terms of the propagation γ and the iterative impedances ζ_1 and ζ_2. Generally we have:

$$a_{11}^{(m)} = (\zeta_1 e^{m\gamma} + \zeta_2 e^{-m\gamma})/(\zeta_1 + \zeta_2)$$
$$a_{12}^{(m)} = 2\zeta_1\zeta_2 \sinh m\gamma/(\zeta_1 + \zeta_2) \quad \ldots\ldots (113)$$
$$a_{21}^{(m)} = 2 \sinh m\gamma/(\zeta_1 + \zeta_2)$$
$$a_{22}^{(m)} = (\zeta_2 e^{m\gamma} + \zeta_1 e^{-m\gamma})/(\zeta_1 + \zeta_2)$$

If these values are used in equation (120) and then inserted together with equation (120) in equation (118) we obtain the required expressions for V_l and I_l in terms of E. The algebra is straightforward but a little tedious. The solutions are:

$$V_l = \frac{\zeta_1 E}{\zeta_1 + Z_s} \cdot \frac{e^{-\gamma l} + t\, e^{\gamma(l-2n)}}{1 - st\, e^{-2\gamma n}} \quad \ldots\ldots\ldots (114)$$

$$I_l = \frac{E}{\zeta_1 + Z_s} \cdot \frac{e^{-\gamma l} + \tau\, e^{\gamma(l-2n)}}{1 - \sigma\tau\, e^{-2\gamma n}} \quad \ldots\ldots\ldots (115)$$

s and t are the voltage reflexion coefficients at the input and output and σ and τ the corresponding current reflexion coefficients already referred to. These are the solutions usually obtained by solving the differential equations of the line and imposing the boundary conditions.

By expansion of the denominators of equations (114) and (115) using the binomial theorem these solutions are interpreted as a standing wave on the line formed by repeated reflexions at the output and input terminals.

Conclusion

The matrix approach to problems involving quadripoles in the form of filters and transmission lines gives a direct and flexible method of handling the theory. The use of differential equations is avoided and the concepts of interest to electrical theory and practice find an immediate interpretation in the symbolism of matrices.

NOTE.

Recently the ideas explained in this article in connexion with quadripoles have been extended by Shekel[9] to deal with multi-terminal transducers. Such an m.t.t. is a network with a set of n-input terminals and n-output terminals instead of the two input and two output terminals of a quadripole.

As in our analysis transfer matrices are derived for the m.t.t.'s and complicated m.t.t.'s are treated as a cascade of simpler ones. Shekel does not restrict himself to networks obeying the reciprocity relations, as we have done. Thus he is able to treat the theory of the distributed amplifier which involves m.t.t.'s with three input and three output terminals.

Acknowledgments

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The BBC V.H.F Sound Broadcasting Station at Wrotham, Kent

THE first of the BBC'S high-power, v.h.f. transmitting stations, at Wrotham, Kent, was brought into full service on May 2nd. It will transmit the Home Service, Light Programme and Third Programme in parallel with the existing long and medium wave stations and will serve a potential audience of some 13 millions in Greater London and the south-east of England.

In recent years the service given by the existing medium and long-wave broadcasting stations operated by the BBC has been restricted by the limited number of wavelengths available for broadcasting within the United Kingdom. Moreover, interference from foreign stations has drastically reduced the coverage—particularly of the Home Service—in many parts of the country.

This situation had long been foreseen by the BBC and as long ago as 1945 the Research Department began a series of tests in order to get first-hand information on the possibilities of broadcasting on very high frequencies. As a result, it was decided, as a long-term project, to carry out comparative tests at high power.

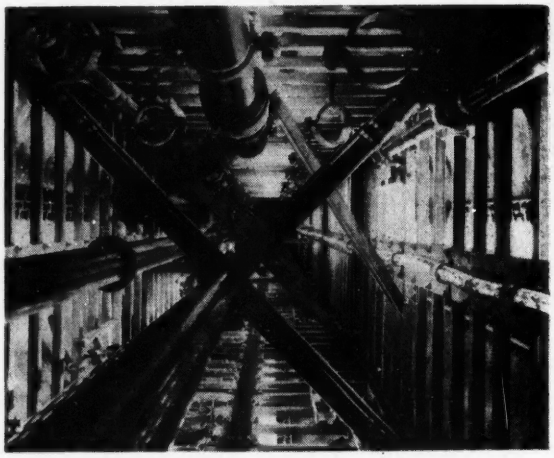
To this end, an experimental station was built in 1950 at Wrotham, Kent[1]. It comprised a single storey brick building and a 470ft mast, the base of which is 730ft above sea level. The station was equipped with a 25kW f.m. transmitter and an 18kW a.m. transmitter both built by Marconi's Wireless Telegraph Co. Ltd, and from July 1950 until March of this year has been radiating on v.h.f. a series of f.m. and a.m. signals. Invaluable experience was gained from these full-scale experiments[2] as a result of which the BBC decided that it would be in the interest of the public to use f.m. for sound broadcasting in the v.h.f. band; this recommendation was subsequently endorsed by the Television Advisory Committee whose second report, published early in 1954, dealt solely with v.h.f. sound broadcasting.

On the basis of its information and the experience provided by the prolonged tests from Wrotham, the BBC'S Engineering Division put forward a scheme for providing a frequency-modulated v.h.f. service which will cover some 98 per cent of the population. This scheme is divided into two parts.

Stage 1, which will cover the main centres of population as quickly as possible and bring a v.h.f. service to about 83 per cent of the population. Stage 2, which will require about 16 further high, medium, and low-power stations, has not yet been approved.

The ten stations comprising Stage 1 with frequency allocations are given in Table 1.

It is expected that v.h.f. stations will be operating from Pontop Pike, Divis and Meldrum by the end of this year and that Wenvoe will be in partial operation. By the end of next year Wenvoe will be completed and further stations will be built at Sutton Coldfield, Holme Moss, Norwich, North Hessary Tor and Blaen Plwy (West Wales). This will mean that v.h.f. will be within reach of some eighty-four per cent of the population of the British Isles.



Inside the cylindrical section of the mast which with the slots in its surface forms the v.h.f. aerial system. The horizontal bars form a screen behind the slots and serve to increase the bandwidth of the aerial. All the slots are fed with currents in phase and of equal amplitude via concentric feeders.

When these first ten v.h.f. stations are completed, Home Service reception will have been made available to an additional 5 300 000 listeners, Light Programme reception to an additional 2 900 000 and Third Programme reception to an additional 11 800 000 listeners. All these listeners are at present out of range of the BBC transmitters and the figures do not include some 3½-4 million Home Service listeners whose reception is at present spoiled by foreign interference.

At Wrotham, the original transmitters were designed so that they could be adapted to work as either f.m. or a.m. transmitters depending upon the outcome of the tests. In fact, the a.m. transmitter was converted to f.m. in January 1954. Since the cessation of the experimental transmissions in March 1955, work has been in progress at Wrotham to install additional transmitters and carry out modifications to those already on site, together with the associated aerial, drive, programme input and other auxiliary equipment.

TABLE 1

Station	*Frequencies (Mc/s)*		
	Light	*Third*	*Home*
Wrotham	89·1	91·3	93·5
Pontop Pike	88·5	90·7	92·9
Divis	90·1	92·3	94·5
Meldrum	88·7	90·9	93·1
North Hessary Tor	88·1	90·3	92·5
Sutton Coldfield	88·3	90·5	92·7
Norwich	89·7	91·9	94·1
Blaen Plwy	88·7	90·9	93·1
Holme Moss	89·3	91·5	93·7
Wenvoe	89·9*	92·1*	94·3*

** Frequencies not yet confirmed.*

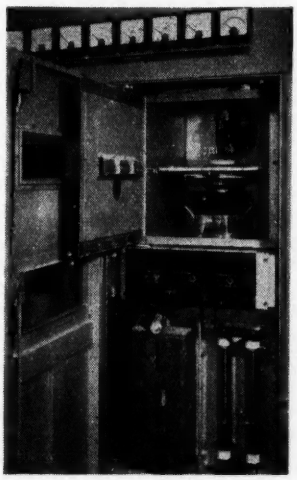
The existing transmitters known as FM1A and FM2A will normally carry the Light and Third Programmes respectively. These are backed up by two new 4·5kW transmitters FM1B and FM2B which will act as spares Two further new transmitters FM3A and FM3B, each of 10kW output will operate together and carry the Home Service. The layout and design of the equipment for the Home Service transmitters has been so arranged that they will, ultimately, be automatic in operation. Certain ancillary equipment common to all three services will also be automatic.

The output and combining arrangements of these six transmitters are unusual and are of considerable interest. In the case of the first two pairs, the failure of the normal transmitter is covered by the reserve; manual switching of the outputs and application of power to the reserve being necessary. The outputs of whichever transmitters of these two pairs are operating are fed to a combining circuit, at the output of which the Light and Third programmes appear as a combined signal. This output is then split into two halves, each half being fed to one section of a further combining circuit.

The output of each 10kW Home Service transmitter is arranged to feed the other section of this combining circuit. Thus at the outputs of the second combining circuit the signal appears as two half-power combinations of Home, Light and Third signals, and under normal conditions these two half-power combined signals are taken over separate feeders to the two halves of the aerial system. By this means the effect of faults developing in the transmitters is reduced to a minimum and the failure of any one transmitter or of one-half of the aerial would be almost undetected except by listeners on the fringe of the service area. In addition, a very comprehensive emergency switching installation is provided to guard against the failure of the various combining circuits and the aerial system.

Duplicate f.m.q. drives are installed for each service and these are fed simultaneously with the programme. Automatic changeover arrangements ensure that either drive may be selected, with the other acting as spare. The f.m.q. system of frequency modulation was developed by Marconi's Wireless Telegraph Co. Ltd and comprises a quartz crystal oscillator connected through a quarter-wave network to a balanced modulator, the susceptance of which varies with the modulating signal, and in turn varies the frequency generated by the crystal oscillator. The crystal is specially cut so that it does not produce spurious harmonics within the operating range. The chief advantage claimed for this system of frequency modulation is that the circuits are much simpler than those of other systems, and therefore more reliable and easier to maintain.

One half of the f.m. transmitter output stage, which consists of two BR128 valves in parallel in an earthed grid circuit.



The output of the crystal oscillator is passed through three stages of frequency doubling and one tripling stage to produce the required carrier frequency. In the case of the two original transmitters FM1A and FM2A there then follow five stages of amplification. The first two are conventional push-pull stages, while the remaining three are single-ended earthed-grid stages with coaxial-line tuning elements. The output stage consists of two BR128 valves in parallel, giving an output of 25kW. Supplies at 6kV and 3kV for the valve anodes are obtained from hot-cathode mercury-vapour rectifiers in the power conversion plant which is installed behind the transmitter.

The 4·5kW (FM1B and FM2B) transmitters are generally similar in electrical design to the earlier ones, the first two stages are push-pull and these feed two single-ended earthed-grid stages provided with coaxial-line tuning elements, one of which forms the output stage.

The new 10kW transmitters (FM3A and FM3B) also follow closely on the design of the earlier transmitters having two push-pull stages followed by three single-ended earthed-grid stages and these three stages are again provided with coaxial-line tuning elements. The final stage has two BR191B valves operating in parallel.

All six transmitters use air-cooled valves. The cooling system of the 25kW transmitters serves a dual purpose, in that air is drawn from outside, filtered, passed through the transmitter cabinets and then is either exhausted to atmosphere or re-circulated within the building for heating in cold weather The re-circulation system is fully automatic and controlled by thermostats. In the case of the 10kW transmitters the air is drawn from within the building and exhausted to atmosphere while the 4·5kW standby transmitters are cooled by air circulation entirely within the the transmitter building.

Since the transmissions are automatically monitored at Broadcasting House no master control position is installed at Wrotham. If, however, a programme fault occurs an alarm will be given on the alarm and indication panel in the control room. This panel is equipped with a series of lamps indicating the condition of the various transmitters, drives, supplies and other auxiliary equipment associated with each programme. Any faults involving plant or equipment at Wrotham will be automatically indicated so that the appropriate action can be taken to remedy the trouble.

Provision is included for the unattended operation of the Home Service transmitter in the early morning. For normal daytime operation three automatic monitors of BBC design, are installed at Broadcasting House, London, and these will compare the outgoing programmes with those received by radio from Wrotham; they are arranged to give an alarm at Wrotham in the event of programme faults being detected. For operation during the early morning, however, changeover panels are provided at Wrotham and Broadcasting House which, when switched to the appropriate position, transfer the Home programme monitor alarms at Broadcasting House. At the same time this permits the Home programme to be sent to Wrotham by either the normal line and programme input equipment or by the Third programme line and its associated programme input equipment (which are not normally required for the Third programme until the evening).

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Reversible Dekatron Counters

By L. C. Branson*, B.Sc., A.Inst.P.

The basic problems involved in the bi-directional coupling of standard Dekatron tubes are briefly stated. A simple modification of the tubes permits the carry signals to be taken from transfer electrodes, and avoids the use of gating circuits. Several bi-directional coupling circuits are described.

DECADE counters employing multi-electrode gas-discharge tubes of the kind typified by the Dekatron GC10B are now well known[1]. In these tubes, the discharge is transferred from any one cathode to an adjacent cathode by applying negative voltage pulses to two groups of transfer electrodes which are interspaced between the cathodes. A unit count is effected by a sequential pair of pulses, one to each group of transfer electrodes, and the direction of transfer is determined by their sequence. Thus a single Dekatron is readily reversible.

Problem With Standard Tubes

However, when additional stages are added to extend the reversible counting range to 10s, 100s, etc., difficulties arise in the derivation of the necessary carry signals. For a uni-directional additive counter, the arrival of a discharge at a zero cathode provides a carry signal from which to derive pulses to operate the following stage. Similarly, in a counter operating on the subtractive sense only, the arrival of a discharge at a number-9 cathode can initiate the carry to the next stage. For a reversible counter in which each unit count may be positive or negative, it is not, however, sufficient to insert resistors in the connexions to the zero and number-9 cathodes and use all the resulting signals. A carry in the positive sense is required only when the count in the first stage progresses from 9 to 0, and not when it regresses from 1 to 0: and similarly a negative carry is required only when the count regresses from 0 to 9, and not when it progresses from 8 to 9. Thus if carry signals be taken from the ninth and zero cathodes, they must be gated according to the direction of counting, and the circuit must be considerably more elaborate than for uni-directional counting.

Modified Tubes

In the counters to be described[2] these difficulties are avoided by taking the carry signals not from the cathodes, but from selected transfer electrodes. For this purpose, special Dekatron tubes were obtained having separate terminals for the two transfer electrodes between the ninth and zero cathodes. These transfer electrodes are herein called the carry electrodes. Fig. 1 shows the arrangement of electrodes and internal connexions, and Fig. 2 shows the symbol adopted to represent the tube, and the basic circuit connexions.

In a first counting stage, a unit count is effected by a pair of pulses, one being applied directly to the nine internally connected transfer electrodes 0_a-8_a and through an impedance Z_a to the tenth, 9_a. A similar circuit is provided to apply the second pulse to the second group of transfer electrodes, 0_b-9_b. Now when the count changes from 9 to 0 in the positive direction, or from 0 to 9 in the negative direction, the discharge passes temporarily in turn to each of the carry electrodes, 9_a and 9_b, to produce differential voltages across the impedances Z_a and Z_b. These constitute the carry signals required for operating the following stage. A carry in this next stage is required, and carry signals are provided, whenever the discharge in the first stage passes to the carry electrodes. Negative voltage pulses are derived from these signals and applied respectively to the *a* and *b* groups of transfer electrodes of the following stage, so that the sense of the carry is correctly determined by the sequence of the signals, *a,b*, or *b,a*.

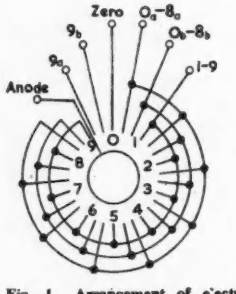


Fig. 1. Arrangement of electrodes and terminals

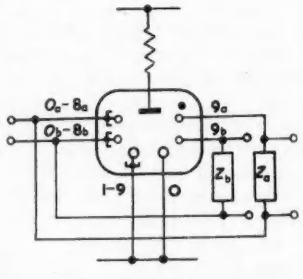


Fig. 2. Basic connexions

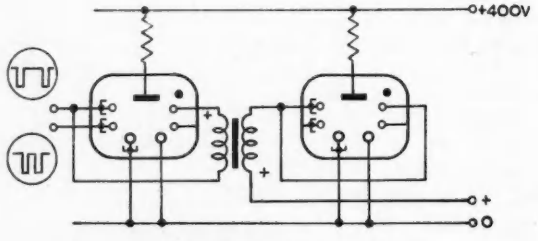


Fig. 3. Simple transformer coupling

Transformer Couplings

The form of circuit chosen to drive a following stage may be varied according to the type of pulses driving the first. In some applications, each unit count is initiated by a pair of pulses of predetermined waveform, duration, and relative delay, and one following stage may then be driven using simple transformer couplings as shown in Fig. 3. The pulses required for one forward and one backward count are indicated. In this, and the succeeding figures, the circuit associated with only one of the two groups of transfer electrodes is shown. Here, each impedance Z is made the primary of a transformer, and the secondary is connected, appropriately phased, between a positive bias

* *Now with Ericcson Telephones Ltd.*

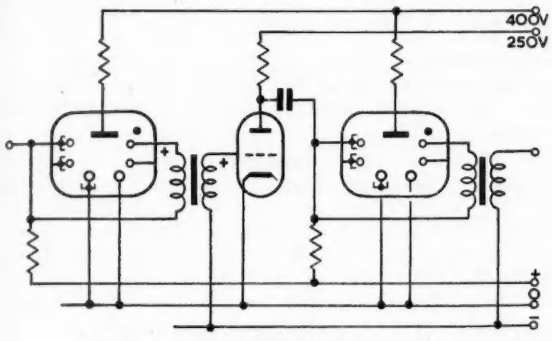


Fig. 4. Coupling by transformers and amplifiers

supply and the corresponding electrodes of the second stage. The shape of the transmitted pulses may be modified by tuning or loading the transformers, but they are inevitably degenerated in amplitude and waveform compared with the pulses to the first stage. Consequently this method has not been extended to further decades.

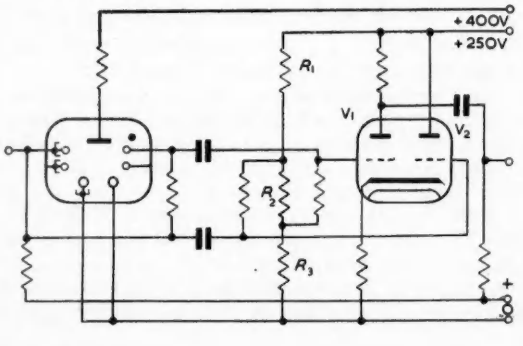
More stages may be coupled by following the transformers with triode amplifiers as shown in Fig. 4, or with cold-cathode trigger tubes. However, such circuits still impose some limitation on the type of input pulses, since they must fail if the duration and relative delay of the pulses are long in relation to the low frequency response of the transformers or to the duration of the pulses provided by trigger tubes. The first pulse to the second stage would then decay, and the discharge return to the adjacent cathode, before the start of the second pulse.

Resistive Couplings

The usable variety of pulses may be extended by making the impedances Z_a and Z_b resistors followed by differential amplifiers. Such an amplifier, *RC* coupled, is shown in Fig. 5. The two valves V_1 and V_2 are so biased by the resistors R_1, R_2 and R_3 that current normally flows through V_2 and not through V_1. Input pulses which transfer the discharge to electrodes other than a carry electrode are applied equally to the two grids, without causing current through V_1. But the arrival of the discharge at the carry electrode, 9_a, makes V_1 grid positive with respect to V_2 grid, so that V_1 passes current. A negative pulse is thus produced in the anode circuit for operation of the following stage.

A further step is to make the amplifiers direct-coupled

Fig. 5. Coupling by resistors and RC coupled amplifiers



as shown in Fig. 6. Here each stage is driven by cathode-followers, V_1 and V_3, which provide low impedance sources and enable the required positive bias to be applied to the transfer electrodes. The grid and cathode of the differential amplifier V_2 are directly connected across the resistor R_1 which is in series with the first carry electrode. The resistor R_2 is chosen so that V_2 is normally biased to cut-off; it has but little effect on the voltage at the carry electrode if a valve with a short grid base, such as a 6SL7, is selected for V_2-V_3. Arrival of the discharge at the carry electrode 9_a causes current through V_2, and the large negative pulse at V_2 anode is fed through the potential divider R_3R_4 to the grid of the cathode-follower V_3, which provides one of the drives to the next stage.

Such a counter may be driven in either sense by suitably phased sine or square-wave inputs over the full frequency range from zero to 3kc/s. The counting rate may be extended by increasing the amplitude of the transfer pulses by by-passing the resistor R_3 with a capacitor. However, if the pulses change the transfer electrode voltages from +40 to −40V relative to the cathodes, the transfer between the *a* and *b* electrodes is effected by a potential difference of 80V, whereas transfers to and from the cathodes are effected by only 40V. The performance is improved if pulses are also applied to the cathodes.

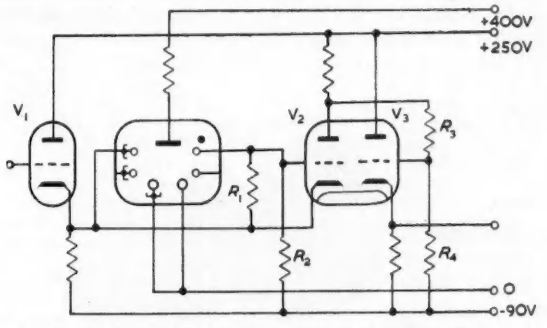


Fig. 6. Coupling by resistors and direct-coupled amplifiers

For this purpose, a common anode resistor is provided for the two valves, and the anode voltage applied through a potential divider to the grid of another cathode-follower which drives the Dekatron cathodes. The cathodes are thus driven negative when both transfer electrodes are positive, and positive when either transfer electrode is negative. In this way, and with rectangular input pulses of suitable mark-space ratio, counting speeds in excess of 10kc/s have been achieved.

By injecting alternate positive and negative counts, the total may be caused to oscillate between 99 999 and (1)00 000 at high speed without loss of control. A carry is transmitted from stage to stage with a delay of some 2·5μsec only. In contrast, in the usual system in which carry signals are taken from the cathodes, the carry is delayed in each coupling by the duration of two pulses, at least 40μsec.

A counter according to Fig. 6 has been in use for the past year. It employs direct coupling throughout. The primary controlling voltages are of sine form, in phase quadrature. They are applied to the deflector plates of a c.r.o. to indicate fractions of a cycle, and also to trigger circuits which provide inputs of square form to the first Dekatron. With this system the discharges may

invest transfer electrodes when a reading is required, but a display of discharges at the electrodes $2,7_a,9_a,9_a$, for example, is simply interpreted as a count of 2799. An alternative system uses flip-flops to cause the passage through zero in the c.r.o. display to coincide with the initiation of a pair of pulses to operate the decade counter. But then a display 1234·0 may indicate a true count of $1234{\cdot}0_1$ or $1234{\cdot}9_9$ according to whether the flip-flops have just operated or are just about to operate. This ambiguity is avoided with the direct-coupled system, which indicates the true count with a display 1234·0 or $1234_b{\cdot}0$ which is interpreted as $1234{\cdot}0_9$ or 1235·0.

Acknowledgment

The author wishes to thank Messrs. Ericsson Telephones Ltd, Beeston, for supplying the special Dekatron tubes used.

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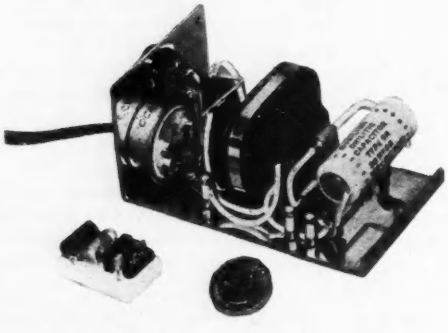
The Economics of the Transistor d.c. Transformer

By G. Grimsdell*

The advent of the power junction transistor makes possible a new method of converting a low voltage d.c. supply to a h.t. supply. In this article this method is compared, from an economic aspect, with the more conventional methods.

A WIDE range of portable or vehicle-borne electronic instruments require high tension supplies at very low currents for their operation. Besides h.t. batteries, there are at present two well-known methods of generating high tension from a low tension d.c. source; these are the rotary machine and the vibrator, transformer, and rectifier.



Two typical junction transistor d.c. convertors

The small unit delivers 30V at 60μA from a 1·5V input, and the larger unit delivers 125V at 40mA from a 12V input, with an efficiency greater than 70 per cent.

The use of power junction transistors makes possible a third method of h.t. generation. It is the aim of this article to examine the economic aspects of the junction transistor h.t. generators or d.c. transformers as they have been called, and to compare them with those of existing methods.

Both the rotary machine and the vibrator have mechanical losses which are relatively independent of the electrical power being handled by a particular machine.

When the electrical output is comparable in power with this fixed mechanical loss, the total efficiency of the device will be low. Thus there is a lower limit of output power beyond which the efficiency falls very rapidly. An average small motor generator with 24V input gives an efficiency of 50 to 60 per cent at 50W and 20 to 30 per cent at 5W. This falls to an even lower efficiency at 2V input, while a typical vibrator power supply gives an efficiency of 70 per cent at 50W and 40 per cent at 5W. At 100mW output both these devices have fallen to a very low efficiency indeed. Turning now to the transistor d.c. transformer it is possible to maintain an efficiency of 60 to 75 per cent or better down to a power level of one or two milliwatts.

Before suggesting the type of application where this new device can satisfactorily compete with existing methods a brief description of its essentials will be necessary.

In general the basic steps of operation are the same as those in a vibrator power supply:—

(1) To convert the d.c. input to a.c.

(2) To transform the low voltage a.c. to a high voltage.

(3) To rectify it and smooth the output.

The fundamental fact that makes the transistor such a good generator of a.c. from a low voltage d.c. is its ability to pass a large current with very low voltage drop across it.

A typical pentode valve may drop some 30V across itself to pass a current of 100mA in the "bottomed" condition.

A junction transistor will drop only 0·2V.

Thus even with a d.c. input of only 6V, the transistor acts as a very efficient switch.

There are two possible modes of design approach:—

(1) To use the transistor as a switch and generate non-sinusoidal a.c. leading to inductive surges, ringing, and the like.

(2) To use the transistor as a sinusoidal generator.

The first method is in general simpler and more efficient, but the latter may be preferable in special cases.

In the second the sinusoidal waveform is perhaps more easily transformed to a high voltage and rectified, but has a much lower efficiency in its initial generation. In general the design problems are those of ensuring that the transistor spends as much of its time as possible in the fully "cut-off" or full "on" condition where its losses are low while keeping to a minimum the partially conducting transition time where losses are high.

Returning to a comparison between the transistor d.c. transformer and other devices it can be seen that there are

* *Mullard Ltd.*

no fixed mechanical losses at all and the fixed electrical losses, caused by the transistor back leakage current, can be kept very low (microwatts). In addition, since no mechanical movement is involved the frequency of operation can be made high enough (1kc/s or above) to simplify the subsequent smoothing problems.

From an efficiency point of view the main use for the transistor d.c. transformer is in the low power level application. This will range from a few watts to about one milliwatt. Here the efficiency of generation is as far as the writer is aware very much better than any other device. It is even good enough to replace the h.t. battery in a number of uses, where it will be found that a low voltage battery and d.c. transformer is cheaper, smaller and more reliable than a high voltage battery.

Among typical applications are supplies for Geiger Müller nuclear counting tubes such as those which require between 400V and 600V at from 10μA to 50μA. The h.t. supply for battery operated cathode-ray tube instruments, h.t. for valve hearing aids (some 30V at 50μA), h.t. for radio frequency valve circuits in otherwise transistor operated battery radio and walkie-talkies, h.t. supplies for insulation testers, photo-multipliers, ionization chambers, see-in-the-dark infra-red image convertors, and many other devices.

Another advantage of the d.c transformer is that, with suitable circuits similar to those of the electronically valve regulated mains power supply, the output voltage can be stabilized against load variations and battery input voltage changes.

Undoubtedly other new applications will be found, once this new device is in use and becomes accepted as a reliable method of solving the h.t. supply problem where very low powers are needed.

Comparison of H.T. Supply Sources

	AVERAGE MOTOR GENERATOR	AVERAGE VIBRATOR POWER SUPPLY	TRANSISTOR D.C. TRANSFORMER	DIRECT H.T. BATTERY
USEFUL POWER LEVELS	Kilowatts to watts	Hundreds of watts to one or two watts	Several watts to one or two milliwatts	Watts to "no lower limit"
MAINTENANCE AND LIFE	Lubrication, brush wear and commutator maintenance. Life very long indeed	No maintenance usually given, but contact erosion usually sets limit of useful life	No mechanical maintenance at all, but device still so new that actual life not yet determined. Some life tests of thousands of hours already completed	Relatively short shelf life, particularly at high temperatures.
WEIGHT AND SIZE	In general, heavier than the other two devices	Lighter than motor generator	Lightest and smallest of the three, particularly at very low power levels	Very high voltage low power batteries have a large ratio of insulation to active ingredients.
VIBRATION AND NOISE	Some vibration and noise, has some gyroscopic effects and sensitivity to acceleration in aeroplanes	Some vibration and noise, has some sensitivity to acceleration and vibration, particularly where designed for maximum efficiency at low output powers	Produces no noise or vibration. Is not sensitive to acceleration or vibration	Produces no noise or vibration. Is not sensitive to acceleration or vibration.
ELECTRICAL INTERFERENCE	Produces some electrical interference, can be suppressed over a given bandwidth	Produces some electrical interference, can be suppressed over a given bandwidth, but with rather more difficulty	Produces no electrical interference as sine/wave oscillator. Produces some electrical interference as non-sinusoidal oscillator but in general easier to suppress than a mechanical contact	No interference at all.
REGULATION	Good, can be fitted with stabilization circuits	Fair	Not very good, but can be fitted with stabilization circuits	Good.
INPUT VOLTAGE RANGE	Any	Any	1·5 to 24V	Any voltage, but bulky and heavy at high voltages.
OPERATING TEMPERATURE RANGE	Up to 150°C or higher	Up to 150°C or higher	Present transistors limited to 60°C or perhaps 80°C. Future types may go up to 150°C	Upper limit of about 80°C.
OUTPUT VOLTAGE	Any	Any	Any	Any
INTERRUPTION FREQUENCY AND SMOOTHING	Very little smoothing required, commutator ripple at kc/s	50 c/s to 500 c/s. Full smoothing required	Any frequency up to tens of kc/s, usual choice about 1kc/s, full smoothing required	D.C., no smoothing at all required.

A Simplified Method for the Design of Logical Conversion Matrices

By M. L. Klein*, S.B., A.M., Ph.D.

Some uses for logical diode matrix networks are described. A numero-graphical method is explained for converting from one numbering system to another. Some possible practical applications for programming sequence control are suggested.

THE purpose of this article is to show how logical networks can be evolved quite simply. In particular, the design of diode matrices is shown to be essentially a translation from one numbering system to another. These networks find use in computers. More recently they have been applied to controlling sequences of events taking place at speeds in excess of the operational speed of relays and in the control of industrial processes where a sequence of events can be programmed. In the latter case, the network is programmed so that certain actions will take place as a consequence of the existence of certain conditions. The network, in conjunction with suitable transducers, senses the existing conditions and acts according to the programme. This is fundamentally what a logical network does. The operation of these networks is easily understood by examining how they translate from one numbering system (such as binary) to another (such as trinary).

Numbering Systems

There are several numbering system in use. Probably the most familiar is the decimal system upon which most day-to-day transactions are based. This system uses ten distinct symbols or marks: the numbers 0 to 9 placed in specific order in accordance with certain rules of sequence which are common to all numbering or counting systems. Numbers such as 1954, 10, 19, 179 203 are thus quite familiar to us.

Earlier civilizations, in a way more ingenious, did not use ten distinct symbols for counting. A numbering system used by the Mayan Indians had only five symbols. Although their symbols did not resemble ours, for simplicity and by convention we will say their numbering system ran from 0 to 4; five distinct symbols only.

The most commonly used system in computers and the simplest uses only two symbols and is called binary code. We will call these symbols 0 and 1. With this system, counting can be accomplished with only two rules of addition and two of multiplication to commit to memory. Moreover, electronically these two operations are performed readily with bistable devices.

More lately, work has progressed using tristable devices allowing use of a trinary or three-symbol code.

Another system uses binary coded decimal in which only the numbers 1, 2, 4 and 8 in our decimal system are used to represent all the numbers between 0 and 9. Thus, 3 is presented as the sum of 1 and 2. The number 5 is the sum of 1 and 4, and so on. This is particularly convenient in allowing binary-operated equipment to be read in decimal magnitudes.

* *North American Aviation Inc., California.*

Conversion to a Common Raster

Since there are several coding systems in use, it is often necessary to convert from one numbering system to another. A simple method to allow conversion from one system to another makes use of a raster or mesh of non-intersecting leads and crystal diodes. In particular, a

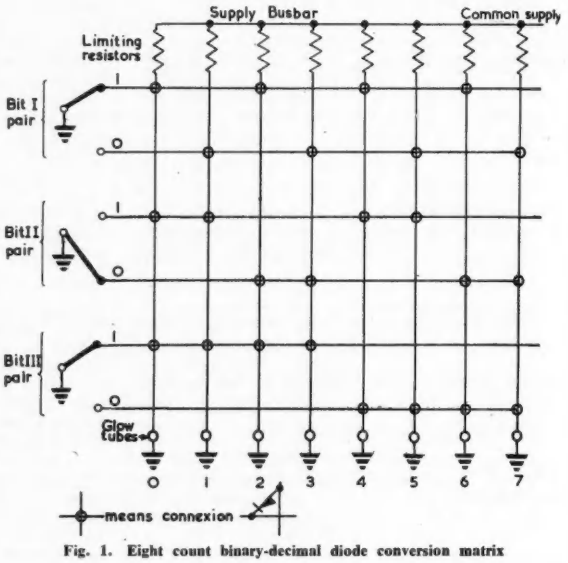


Fig. 1. Eight count binary-decimal diode conversion matrix

method using a common raster will be discussed which permits a plug-board construction. This permits changing the conversion matrix quite simply depending upon which number system is being translated. More important, while it does not use the minimal number of diodes possible, it is readily understood. We will first be concerned with converting the input code to the vertical leads of the common raster.

The conversion is ordinarily accomplished electrically with a diode matrix. Refer to Fig. 1. This is a binary to raster matrix. Setting up the binary numbers on the switches at the left implies that certain lines are grounded and certain lines are not grounded. At the top of a matrix is a voltage supply bus-bar, and each vertical line has a current-limiting resistor. If the orientation of the binary code switches is such that the current can flow through a diode to ground, the line supply potential is dropped across the current-limiting resistor and the neon light at the

bottom of the line will not glow. On the other hand, if the vertical line is not grounded anywhere, part of the potential is available to light the neon bulb at the bottom of the line. Notice that no matter how the switches are oriented, one and only one vertical line is ungrounded at a time and therefore a single lamp glows at a time. This is a logical network to the extent that a certain set of conditions (binary numbers) lead to a certain unique conclusion (a single glowing tube).

Suppose now we are confronted with the problem of constructing this matrix—that is, designing the array of diodes and interconnexions. This can be done with Boolean algebra with some labour. An alternate procedure, which performs the same logic, can be set down to reduce the problem to a single graphical process. It is necessary to know how many decimal numbers are to be represented—that is, 128, 8, 904 093 and so on. A vertical line is ruled for each number. In Fig. 2, for simplicity, we have used a sixteen lead raster. We are to convert to 0 to 15 from a

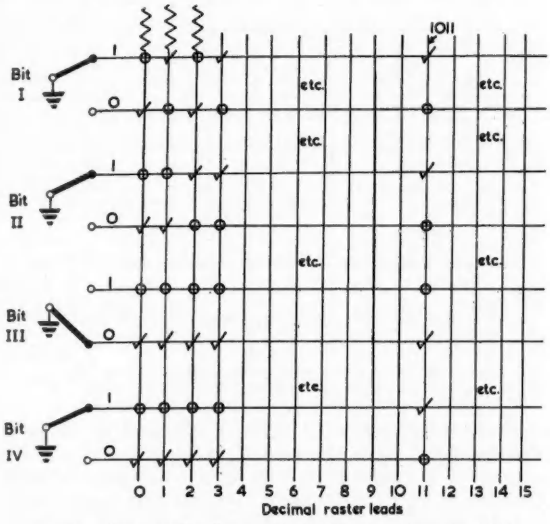


Fig. 2. Sixteen count diode matrix in binary configuration 1011

binary code. In binary, we recognize that four bits or columns of 0's and 1's are needed to represent all the numbers from 0 to 15. In general, the power of the number of marks in the system gives the number of bits (binary digits) needed to represent (no. marks)^n decimal numbers. Since a binary system has two marks, $(2)^4 = 16$ decimal numbers, and therefore four bits will represent any decimal number from 0 to 15. Orthogonal to the vertical leads we draw a pair of lines for each bit required. Here we require (see Fig. 2) four pairs of lines, and the top of each pair has been marked "1" and the bottom of each pair "0." Thus, each of the pairs represents one of the binary numbers in the bit, and a switch connecting "1" to ground means the bit has the significance of "1", and connecting "0" to ground means the bit has the significance of "0."

We have adopted the convention that the topmost pair is the right-hand bit. Therefore, the top switch touching "1," the second "1," the third "0" and the fourth "1" represents the binary coded number 1 011. It is important that the convention be kept in mind.

The next step is to construct a table of numbers converting binary to decimal. Thus, for sixteen numbers:

TABLE 1

BINARY	DECIMAL	BINARY	DECIMAL
0 000	0	0 111	7
0 001	1	1 000	8
0 010	2	1 001	9
0 011	3	1 010	10
0 100	4	1 011	11
0 101	5		
0 110	6	etc.	

The next step is to "read" the chart on to the raster. This is done by making a check mark at the intersections of the horizontal (binary) and the vertical lines in the following way:

1. Refer to the conversion table, choosing one decimal number and its binary code.
2. Identify the vertical lead with the decimal number.
3. Check the intersection of this lead with each horizontal lead representing the binary code for the number.

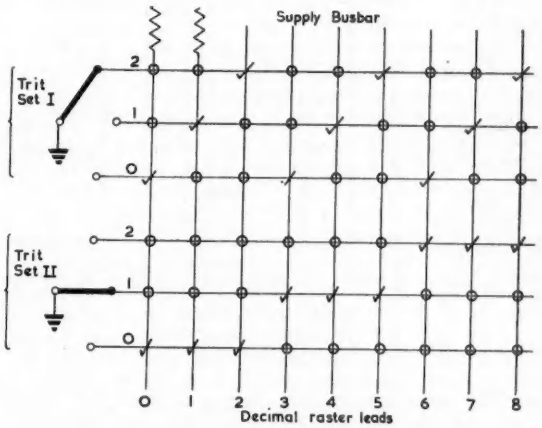


Fig. 3. Nine count trinary diode conversion matrix

For example, for decimal 0, one finds checks at each intersection of the 0 vertical line with a 0 horizontal line. For decimal 2, one finds checks at the intersection of the 2 vertical line with horizontal 0 topmost, 1 next pair down, 0 next pair down, 0 last pair down. This, by the convention adopted above, reads binary 0 010, which from Table 1 we see is decimal 2. The final step is to indicate a diode at each intersection where a check has not been placed. The result is the matrix performing the unique conversion to a single vertical lead for any orientation of grounding switches representing binary code. As a further example, a trinary to raster conversion will be performed. Fig. 3 shows the raster. We will now use nine decimal numbers which are represented by two sets of three lines. Notice with a three-number system, each set of horizontal leads has three lines instead of the two of binary. In general, each set requires as many lines as there are distinct marks in the numbering system. In binary there are two, in trinary three, in quinary five.

We now set down the table converting trinary to decimal.

TABLE 2

TRINARY	DECIMAL	TRINARY	DECIMAL
00	0	12	5
01	1	20	6
02	2	21	7
10	3	22	8
11	4	—	—

Next we check each line intersection, following the same convention as before, topmost set of leads representing the right-hand column of trinary numbers. All unchecked intersections are diode-connected to produce the result wanted.

Operational Usage

This same sort of reasoning can be used to perform an operational control on a system which performs a thinking operation in a sense. Take the trinary system of Fig. 3 and redraw it. As Fig. 4, it will now be considered as representing one of three positions of an aeroplane elevator and one of three attitudes of the aeroplane. There are nine distinct combinations of the elevator position and the resultant aeroplane attitude. Each of these we represent as a trinary number. It is assumed that the elevator positions up, neutral, down are indicated by the switch as well as the aeroplane attitude up, neutral, down. Let us free the pilot from worrying about some things by programming that when the elevator is up, the plane's attitude must be up; when down, the plane's attitude must be down; when neutral, the plane is neutral or straight and level. If these situations exist, everything will be considered normal and we will not notify him of these conditions. However, if the elevator is down and the plane goes up or remains straight and level, or the elevator is up and the plane goes down or straight and level, or any other situation but the previously mentioned three exists, he should be notified that things are not as they should be. This we will do by ringing a bell.

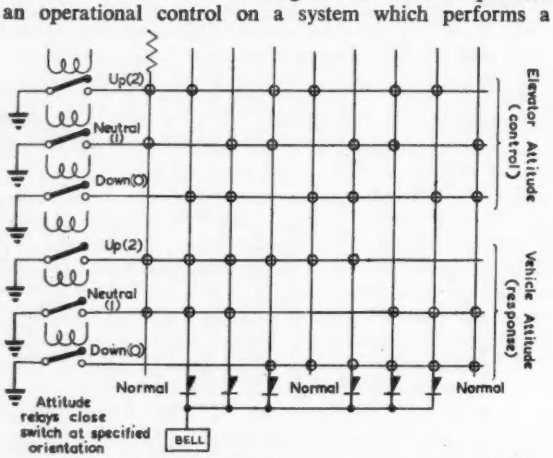


Fig. 4. Trinary to decimal conversion matrix applied as an operational indicator

NORMAL STATES—NO SIGNAL

Up-up ; *trinary* 22 ; *dec.* 8
N-n ; *trinary* 11 ; *dec.* 4
Dn-dn ; *trinary* 00 ; *dec.* 0

This problem is precisely the logic of a trinary to raster conversion matrix. Those decimal numbers (see Table 2) representing any condition but the three acceptable ones are terminated through a diode connexion to the common bell. Thus, any indication of a non-acceptable set of conditions will warn the pilot.

It is obvious how this can be expanded to deal with a multiplicity of possible operational states and their possible results to perform logical operations for any given combinations of states. The methodology indicated for numbers would be perfectly adaptable.

Conversion from Raster to Arbitrary Code

Having obtained decimal equivalents of an arbitrary input code by causing a signal to arrive on a distinct line, we are interested in a method for developing a diode matrix for coming back out with any other arbitrary code. This is again a matrix developed by graphical means. Refer to Fig. 5. Say we choose to come back out with a binary code. This means the signal must be fed to those lines representing the binary digits of the decimally numbered leads. This is the same as Table 1. Now we again draw the vertical raster for each decimal number of the system and the horizontal pairs of lines representing the binary code, topmost pair again representing the right-hand bit. We again check the intersectional points representing the binary numbers for each decimal number. However, to go from raster to code, we now connect at those points where the checks are made with a diode. The diode direction is found by inspection and must allow current to pass to the proper horizontal leads. A resistor is shown at the end of each binary line to develop a voltage when the current flows through it, and this voltage can be used as needed.

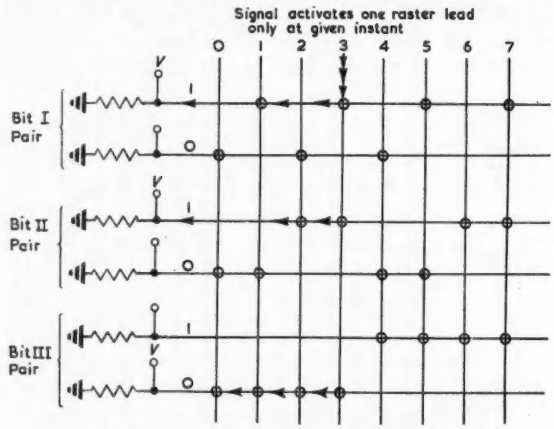


Fig. 5. Raster to binary eight count diode conversion matrix
Specific conversion shown converts decimal 3 *to binary* 11.

Code to Raster to Code

There remains to connect the two matrices together. This quite obviously would consist of connecting the appropriate common raster vertical lines of the input decoder to the output coder. Thus, connecting the raster lines of Fig. 3, trinary to common, to the raster lines of Fig. 5, common to binary, would produce a composite matrix which would instantaneously convert a trinary code to a binary code. Any arbitrary input can be converted to any other arbitrary output. The raster becomes convenient as a standard intermediary, since a uniform plug patching arrangement can be devised for all output coding matrices.

An Expanded Time-Base Using a Miller Integrator

By V. N. Rao*, M.Sc., A.M.I.E.E., and V. Sankarasubramanyan*, B.E.

This article deals with a special type of linear time-base in which the sweep speed is enhanced over a small portion. This time-base can be used for accurate range measurement in fire-control radar and also for increasing range resolution in the early-warning radar sets which use A-scope representation.

IN radar, the simplest method of representing echoes from targets and of measuring range is by means of A-scope representation where the cathode-ray spot moves horizontally at a constant speed. This sweep may represent either a small part of, or nearly all the period between successive pulses. Knowing exactly the instant at which the sweep starts relative to the transmitted pulse and also the time interval occupied by the sweep, the exact range can be determined. The accuracy of this is, however, limited by the operator's ability to align the echo and the calibrator signal. If an attempt is made to increase the accuracy of this determination by increasing the time-base speed so that the entire length of the cathode-ray trace corresponds to a smaller period of time, then there is the drawback that only a small part of the observable range is being shown on the cathode-ray tube. This difficulty can be overcome by using a sweep in which the sweep speed is enhanced over a small portion at a point corresponding to the echo under consideration. This expanded portion will now occupy a larger part of the cathode-ray trace than before and hence over the expanded portion a given length of the trace will represent a smaller increment of range. In this manner the accuracy of range determination can be increased. This method does not cause any appreciable reduction of the total range represented by the time-base. This type of time-base has been used[2] for accurate range determination in Naval fire-control radar. This can also be used in early warning radar sets where the time-base can be expanded at any point desired and hence the range resolution improved at that point.

The circuit described here provides such an expanded time-base using a conventional Miller integrator. Fig. 1 shows the entire circuit. In this circuit, a pulse derived from the radar transmitter is applied to the cathode coupled multivibrator shown by valve V_1 and associated circuit. At the anode of the second triode section of V_1 a positive rectangular waveform is obtained and the front edge of this waveform corresponds in time to the front edge of the transmitted pulse. This waveform is applied to the suppressor grid of a pentode V_2 which is connected as a Miller integrator. Normally, without any output from V_3, the waveform at the anode of V_2 will be a linear voltage fall terminated by the minimum voltage possible at the anode of V_2. With the values used in the circuit, the duration of the time-base is about 600μsec. The portion of the circuit containing the valves V_3 to V_7 is for producing a large positive pulse whose position can be moved anywhere along the time-base.

In order to produce the positive pulse mentioned above, the negative rectangular waveform from the anode of the first triode section of the valve V_1 is applied to the control grid of V_7. Due to the action of the capacitor C_2 a sawtooth waveform is produced at the anode of V_7. This waveform is applied to the control grid of a sharp cut-off pentode V_6, the cathode of which is returned to an adjustable positive potential. By moving the positive potential on the cathode, a rectangular waveform with a variable negative edge can be obtained. This is then differentiated and the negative pulse sliced and amplified in the stages comprising of V_5, V_4 and V_3. Slicing is done by V_5, which is a sharp cut-off pentode and the sliced pulse is shaped and amplified by the valves V_4 and V_3. A beam power tetrode is used in the last stage of this circuit to provide a large positive pulse in the output.

The grid leak resistance of the Miller integrator comprises two resistors R_1 and R_2 and the positive pulses from V_3 are applied across one of them (R_2) as shown in Fig. 1. The potential to which the grid leak resistance is returned will therefore be a positive voltage E_{ht} superposed by a positive pulse of amplitude E_o. The rate of fall of the voltage at the anode of V_2 can be shown to be given by:

$$de/dt = -\frac{AE}{C_1R_g(A+1)}$$

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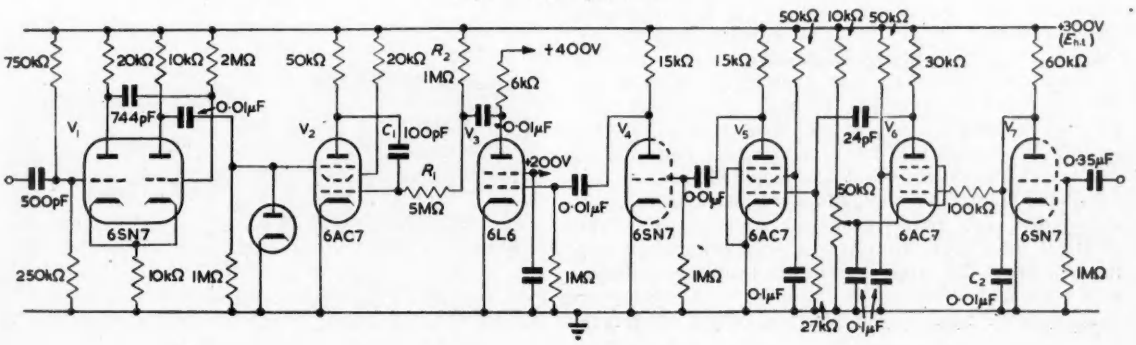
Fig. 1. The complete circuit



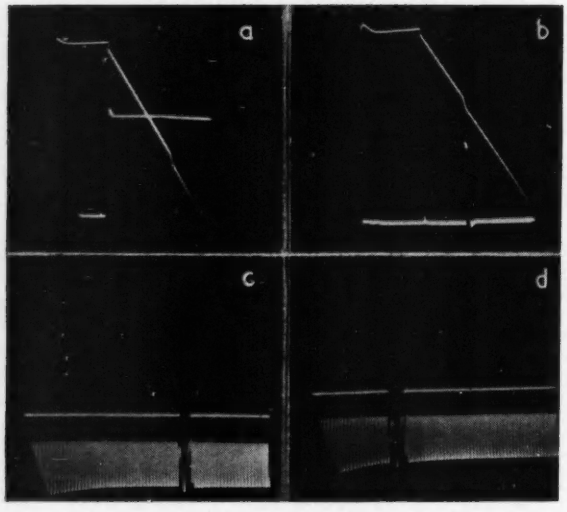


Fig. 2. Circuit waveforms

where A = Voltage amplification of V_2

$R_g = R_1 + R_2$

E = the potential to which the grid leak resistance R_g of V_2 is returned.

As a result of the application of the positive pulse, the time-base will have a constant slope over all the portions except over the portion where the pulse is applied. Here the slope will be higher by an amount which depends on the ratio of the pulse amplitude E_o to the voltage E_{ht}. By varying the amplitude of this pulse, the slope of the expanded portion can be varied. Also by varying the cathode potential of V_6, the position of the expanded trace can be moved.

Some of the waveforms obtained with the above circuit are shown in Fig. 2. The time-base waveform along with the waveform at the second anode of V_1 is shown in Fig. 2(a). The time-base along with the pulse can be seen in Fig. 2(b). In order to demonstrate the improvement in range resolution with this type of time-base, oscillations obtained in a ringing circuit are shown in Fig. 2(c) with this time-base applied to the X plate of the cathode-ray tube.

The pulse which causes the expansion of the time-base is also shown in the figure for comparison. The effect of moving the position of the expanded portion may be seen by comparing Figs. 2(c) and 2(d). Also it can be seen from these figures that the speed of the expanded trace is about three times that of the rest of the time-base.

REFERENCES

1. WILLIAMS, F. C., MOODY, N. F. Ranging Circuits, Linear Time Base Generators and Associated Circuits. *J. Instn. Elect. Engrs. 93*, Pt. 3a, No. 7 (1946).

2. LAWS, C. A. A Precision Ranging Equipment using a Crystal Oscillator as a Timing Standard. *J. Instn. Elect. Engrs. 93*, Pt. 3a, No. 2 (1946).

A Transfer Function Analyser

An equipment is described which will indicate to a first order, the resolved components of a test signal at the output of a servo amplifier or similar device. The indication provided remains accurate when harmonic distortion is present, even when this interference is comparable in amplitude to that of the fundamental test frequency. The transfer function analyser is also suitable for analysis of passive networks which have an overall loss.

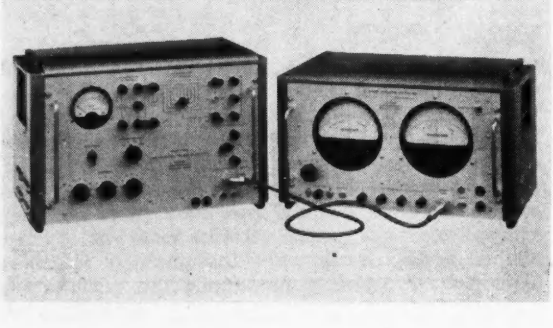
IN the course of servo-mechanism development and manufacture, it is customary to examine performance in terms of phase and amplitude characteristics over the frequency range concerned. In the development stage where complete information is required, it is usual to plot this information in the form of a polar diagram (i.e. Nyquist diagram). (Automatic presentation of results in the form of a Nyquist diagram have so far failed to discriminate against harmonics). In production testing however measurement at say three fixed frequencies will usually provide the necessary proof of satisfactory performance.

The measurement of phase and amplitude may on first consideration appear a straightforward matter as it can be argued that such measurements are commonplace in the electrical laboratory. However, servo-engineers are only too well aware that while a servo can readily be disturbed with sinusoidal influence, the presence of non-linearities in the system frequently give rise to an output which is far from sinusoidal. Consequently, if the results of measurements are to be reliable, it is essential that the technique employed be capable of operating on the fundamental component only and discriminating against harmonics and unrelated frequencies which may be present, and the system of measurement should then give an overall accuracy to within (say) ± 1 per cent. The Transfer Function Analyser was primarily developed for use in the design and testing of servo systems and the above mentioned need for high discriminating power of overall accuracy received foremost consideration. The complete equipment comprises two separate units:—

(1) L.F. oscillator OS.103, and

(2) L.F. phase sensitive voltmeter VP.253.

The transfer function analyser.



Principle of Operation

The oscillator provides a sinusoidal electrical disturbance of known voltage and frequency to the system under test. The resulting signal, at the desired point of measurement, is then directly indicated by the low frequency phase sensitive voltmeter. This instrument displays the measured signal in the form of two resolved voltage components, utilizing the oscillator output voltage as phase reference. The phase sensitive voltmeter employs the wattmeter principle for phase resolution and consequently achieves the desired characteristic that the measurements obtained are unaffected by the presence of harmonics or unrelated frequencies.

Brief Specification

Frequency Range

Nominal range 0·5c/s to 1 000c/s.

As the frequency is reduced below 0·5c/s the indicating meters will give increasing response within the cycle. By noting the mean value of the pointer swing, useful readings can be obtained down to 0·1c/s. The oscillator section covers a frequency range of 0·01c/s to 11·1kc/s.

Forcing Voltage

The oscillator provides known voltage from 10V r.m.s. to 10mV unbalanced or 20V r.m.s. to 20mV balanced. For cases of low input impedance the oscillator will provide current drive up to 10mA r.m.s.

Input Ratio (L.F. Phase Sensitive Voltmeter).

Full scale indication for 50mV to 150V thus giving useful ratio of at least 30 000 : 1.

Accuracy

Frequency accuracy ±1·5 per cent
Amplitude „ ±3 per cent
Phase „ as determined by resolved

component display will be better than ±2 per cent.

Operating Procedure

Fig. 1 illustrates the basic operational set-up for the Transfer Function Analyser.

The oscillator operates at constant level of 10V r.m.s. per phase and a special cable connects the 4 phase output to the phase sensitive voltmeter for reference energization.

A calibrated attenuator provided in the oscillator permits a suitable known voltage to be applied to the work. Having chosen the most suitable sensitivity range for the voltmeter, all that is required is to rotate the frequency controls of the oscillator over the desired range, readings being noted at suitable intervals.

Where spot checks only are required as for production testing, the decade tuning system of the oscillator facilitates rapid selection of the desired frequencies.

The oscillator output voltage is stabilized to within ±5 per cent over its entire frequency range of 0·01c/s to 11·1kc/s. Variation over limited sweeps will be considerably less and consequently readjustment of the level control is necessary only when the highest possible accuracy is required.

The required voltage gain in the phase sensitive voltmeter is obtained in a three stage d.c. amplifier with blocking between stages. The resulting phase shift at low frequencies is neutralized to a first order by equivalent blocking on the reference inputs.

The problem of amplifier drift is thus eliminated with the introduction of negligible phase error.

Carrier and Non-electric Servos

A considerable number of servo systems utilize in themselves either electronic or magnetic amplifiers and in such cases the transfer function analyser is suitable for direct application. When carrier techniques are employed it will be necessary to modulate the electrical disturbance on to the carrier and to de-modulate the resulting signal before it is applied to the phase sensitive voltmeter. In instances where

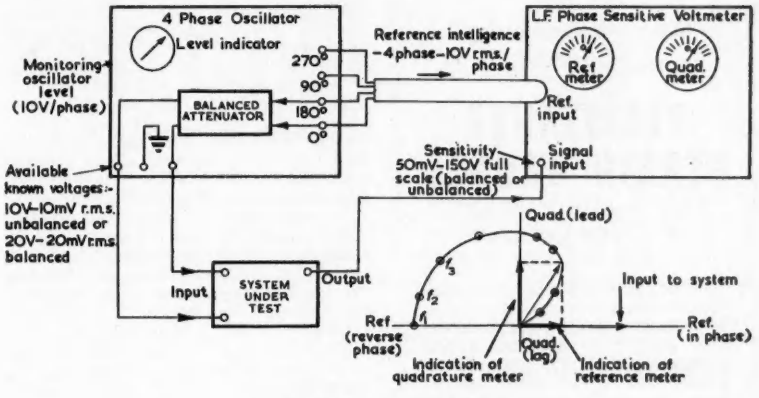


Fig. 1. Basic operational set-up

the servo system has no electrical link, transducers and pick-ups will be required in order to get the necessary intelligence into and out of the system in question.

In such cases as mentioned above, where it is necessary to employ equipment in addition to the transfer function analyser, the transfer characteristics of this equipment alone may be readily determined utilizing the transfer function analyser, and corresponding allowance made in the final results.

Vibration Analysis using Transfer Function Analyser

The transfer function analyser is well-suited to the investigation of the behaviour of large structures when subjected to forced vibration.

A typical example is an airframe under test. The forced vibration is applied by way of the oscillator, a power amplifier and a vibration motor. The aircraft is supported by its own tyres at reduced pressure level. A number of pick-ups are located at various parts of the airframe and switched in turn to the phase sensitive voltmeter. One pick-up is usually chosen as reference point and all measurements of amplitude and phase are then noted relative to the reference point. This procedure eliminates phase error due to the power amplifier and vibration motor.

Acknowledgments

The equipment described is manufactured by the Solartron Electronic Group Ltd. of Thames Ditton, Surrey.

BOOK REVIEWS

Dielectrics and Waves

Edited by A. R. von Hippel. 284 pp. 115 figs. Demy 8vo. Wiley & Sons Inc., New York. Chapman & Hall Ltd., London. 1955. Price 128s.

PROFESSOR von Hippel, who is the Director of the Laboratory for Insulation Research at M.I.T., is one of the leading American workers on the subject of dielectrics and has used his wide experience of the subject to write a comprehensive review. Dielectrics are of interest not only to electrical engineers but also to physicists and chemists and the aim of the author is the very laudable one of combating specialization by discussing insulating materials in a way designed to interest these three groups of workers. The electrical engineer is usually only interested in the "macroscopic approach" in which a material is described by the three constants, permittivity, permeability and conductivity, and this forms the theme for the first part of the book. The interest of the chemist and the physicist is in the "microscopic approach" by which the material properties are related to the molecular structure and this is discussed in the remainder of the book.

The first section of some 90 pages gives a conventional treatment of electric and magnetic fields, developing Maxwell's equations and giving solutions for plane wave and waveguide propagation. Vector methods are used, an appendix giving the results which are required, but the condensed nature of the treatment makes it unsuitable for anyone coming to the subject for the first time.

The latest "Electronic Engineering" monograph

RESISTANCE STRAIN GAUGES

By J. Yarnell, B.Sc., A.Inst.P.

Price 12/6 (Postage 6d.)

This book deals in a practical manner with the construction and application of resistance gauges and with the most commonly used circuits and apparatus. The strain-gauge rosette, which is finding ever wider application, is treated comprehensively, and is introduced by a short exposition of the theory of stress and strain in a surface.

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Electronic Engineering

28 ESSEX STREET, STRAND
LONDON, W.C.2

The second section is less familiar to the electrical engineer and so of more interest. The keynote of the author's development of the subject is that enough is now known of the relation of the electrical constants of a material to its molecular structure for it to be nearly possible to "engineer" materials to have desired properties. The importance of this idea to the development of electrical engineering is obvious and it is desirable that research engineers should know what can in fact be done. A necessary step is a knowledge of present theories of atomic and molecular structure and this topic is introduced together with a descriptive account of wave mechanics. The author has succeeded in producing a clear summary of what is essentially a difficult subject.

The remainder of the book applies the ideas of the molecular structure in discussing a variety of topics including dielectric and magnetic effects, piezoelectricity, ferroelectricity, conduction and breakdown. The only major criticism which can be made is that the author has tried to do too much, and as a result many of the topics introduced have to be dropped just as they become most interesting. This is offset, however, by numerous references to published papers.

JOHN BROWN.

Handbook of Microwave Measurements

Edited by Moe Wind and Harold Rapaport. 1,000 pp., 500 figs. Royal 4to. Two volumes. Polytechnic Institute of Brooklyn. 1954. Price $12.00.

THIS book is an attempt to present in the simplest possible form a large number of microwave measurement techniques. As the editors point out, most quantities can be measured by several different methods, and it has been their aim to present as many different methods as possible for each type of measurement. There are 20 chapter headings, covering all the common measurements such as frequency, standing-wave ratio, Q-factor, antenna measurements, etc., and some less common ones, such as voltage breakdown, r.f. leakage, and duplexing tube characteristics.

Clearly, a primary objective has been to explain the experimental methods in the simplest possible way, even to the extent of employing a step-by-step description of the procedure which the reviewer suspects is not really necessary in most cases.

For example, the procedure for measuring frequency with a "frequency meter with an internal indicator" begins as follows:—

"1. Select a frequency meter that will cover the approximate range required.

2. Plug or screw the antenna used with the frequency meter into the receptacle supplied (if necessary).

3. If an 'on-off' switch is supplied, turn it to the 'on' position and allow thirty seconds for the warm-up of the tubes."

The final step is:—

"9. If necessary, make use of equation (1) to convert wavelength to frequency or vice-versa."

This is followed by an account of the procedure for using a "frequency meter without internal indicator".

The above example is an extreme one, but in many other places obvious advice is given at great length. Another gem is—"To determine the accuracy of a specific instrument, refer to the applicable instruction book"!

For some measurements sources of error are considered most carefully, for others the treatment is rather superficial. For example, a limit is set to permissible v.s.w.r. of the receiver in measuring the directivity of a directional coupler, but no indication is given of the effect of this on the final result.

Having made these criticisms, it must be said that the book contains a great deal of very useful material, and the plentiful detailed numerical examples will be found most helpful by the beginner in this field of work.

The book is Lithoprinted in facsimile of typewriting, no doubt for economy, and the lines are not justified, so that the general appearance is not particularly attractive. Volume I contains the text, and Volume II the illustrations. This arrangement has some advantages (for example, the illustrations are really adequate in size and are always easily referred to), but a drawback is the large amount of desk space taken up when both volumes are open at the same time.

A. L. CULLEN.

Protective Wrappings

By C. R. Oswin. 268 pp., 50 figs. Demy 8vo. Cam Publications Ltd. 1955. Price 32s.

THIS collated work was first published in the form of a series of articles in The British Packer. Mr. Oswin has spent many years on research into the properties and applications of wrappings. He has become well known throughout the world as a leading authority on the subject.

The book is an analysis of the use of thin flexible wrappings for protecting perishable merchandise. It presents the manufacturer with a means of restricting his field of choice, consequently reducing the amount of experiment necessary for the final selection of a wrapping material. It is in three parts, each complete with references, and describes the common commercial wrappings selection for generalized purposes, and specific applications.

Television

By V. K. Zworykin and G. A. Morton. 1,037 pp. 280 figs. Demy 8vo. 2nd Edition. John Wiley & Sons Inc., New York. Chapman & Hall, London. 1954. Price 140s.

THE second edition of this comprehensive treatise on television practice recommends itself once again by the reputation of its authors. First published in 1940, when television was still a novelty to the general public, and a headache to industry, it comprised some 600 pages. The 1954 edition of over 1 000 pages, reflects the considerable progress made in the entertainment side of television since those early days, and its many new applications in the industrial field. It is lamentable that this same progress has also increased the price of the book from 36s. to 140s., which will debar many who would profit from its possession from having it on their bookshelves. This is an example of a situation to which publishers of text books must give increasing attention.

The original character of the book, which covers the whole range of the subject from fundamental physics to engineering applications, has been retained. Every chapter has been revised and brought up to date. New devices, such as transistors, are included within the original framework. Two new sections have been added, dealing respectively with Colour Television, and Industrial Television. Of course the general approach is American in viewpoint, although generous reference is made to British and other contributions. There are some notable omissions however, particularly our work on flying-spot continuous motion film-scanners, our contribution to camera-tubes, and work on using television processes for film production. The bibliography given at the end of each section is comprehensive, but not complete.

In conclusion, it should be said that anyone remotely connected with television will profit by reading this book.

L. C. JESTY.

Protective Current Transformers and Circuits

By P. Mathews. 253 pp. Demy 8vo. Chapman & Hall Ltd. 1955. Price 36s.

THIS book is one of a series recommended for publication by the Technical Papers Panel of the British Thomson-Houston Company, Rugby. It has been written in the interests of those concerned with advanced theory and practice of engineering. A careful selection of material has been made so as to give a consistent and adequate theoretical groundwork and to illustrate its application to practical problems.

Radar Pocket Book

By R. S. H. Boulding. 176 pp. 70 figs. Post 8vo. George Newnes Ltd. 1955. Price 15s.

THIS book provides, in clear and concise form, information on the basic electrical principles and formulae applicable to radar, together with data on the various parts of a radar installation. It is well illustrated, and includes many typical circuit diagrams of the different units of modern radar equipment, with their operation clearly explained. Engineers and operators concerned in the construction, installation and use of radar equipment will find this compendium useful.

Frontier to Space

By Eric Burgess. 174 pp. 50 figs. Demy 8vo. Chapman & Hall Ltd. 1955. Price 21s.

THIS book gives an account of how modern rockets are enabling man to obtain knowledge on conditions at the frontier to interplanetary space in order that he will be able to predict the behaviour of vehicles moving at high speeds in the rarefied upper regions of the earth's atmosphere. Most of the book could be read with interest by persons with little, if any, scientific knowledge. A few parts require a moderate knowledge of the engineering sciences and mathematics. There is an interesting foreword by the Astronomer Royal, Sir Harold Spencer Jones.

Magnetic Alloys and Ferrites

Edited by M. G. Say. 200 pp., 55 figs. Demy 8vo. George Newnes Ltd. 1954. Price 21s.

THE object of this book is to provide information on the wide variety of materials now at the disposal of the electrical engineer and component designer. In the first section of the book Professor Brailsford gives an account of modern views on the fundamental processes of magnetization. The related subjects of materials for magnetic recording and magnetostriction, together with magnetic compensating and non-magnetic alloying are included.

Chemical Engineering Instruments and Control Methods

Edited by E. Molloy. 182 pp., 100 figs. Demy 8vo. George Newnes Ltd. 1954. Price 21s.

THIS book has been compiled to provide a practical guide for industrial chemists and chemical engineers both in the chemical industry and in the various industries where chemical engineering techniques are employed in the manufacturing processes.

Generation and Transmission

By C. S. Beckett. 124 pp., 50 figs. Demy 8vo. 3rd Edition. Blackie & Sons Ltd. 1954. Price 8s. 6d.

IN this book the author has attempted to present these two subjects in such a way that the student may obtain a good general knowledge of them. A great deal of the material is naturally descriptive, and although it has not been possible to go into detail about all parts of the equipment, points of major importance have been emphasized. The general standard is that of an engineering degree and the work, as a whole, is intended to meet the needs both of the university and technical college student and of the practising engineer.

CHAPMAN & HALL

A JOHN WILEY PUBLICATION

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1953 Issue

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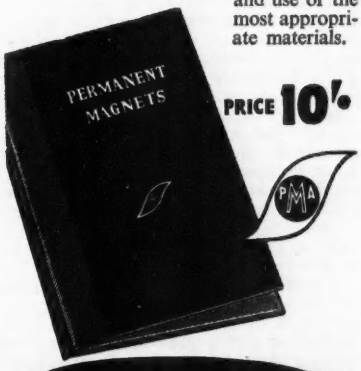


PERMANENT MAGNET ASSOCIATION

301 GLOSSOP ROAD, SHEFFIELD 10

ELECTRONIC EQUIPMENT

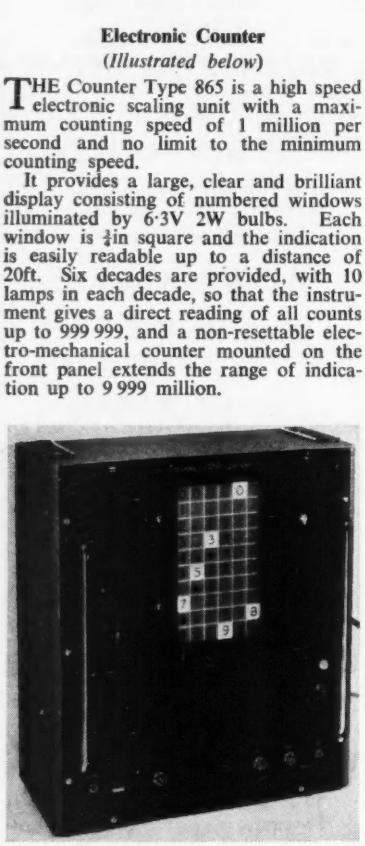
A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Electronic Counter

(Illustrated below)

THE Counter Type 865 is a high speed electronic scaling unit with a maximum counting speed of 1 million per second and no limit to the minimum counting speed.

It provides a large, clear and brilliant display consisting of numbered windows illuminated by 6·3V 2W bulbs. Each window is ¾in square and the indication is easily readable up to a distance of 20ft. Six decades are provided, with 10 lamps in each decade, so that the instrument gives a direct reading of all counts up to 999 999, and a non-resettable electro-mechanical counter mounted on the front panel extends the range of indication up to 9 999 million.



The main display may be switched on or off at will without affecting the operation of the counter in any way, and this facility ensures, negligible wear of the lamp switching relays.

The instrument will count any input of negative peak amplitude between 1·5 and 50V providing the waveform passes through zero once every cycle. Hence sinusoidal signals and both recurrent and random pulses can be counted. A gating circuit is incorporated to enable the counting operation to be switched on and off both manually and by means of an external signal. The speed of operation is such that no errors are introduced up to the maximum counting rate of one million per second.

Resetting the counter to zero is accomplished either by operation of the reset switch or by externally closing a circuit. Since both gating and resetting operations may be carried out externally, the instrument may be employed in conjunction with suitable auxiliary equipment for making time, speed and frequency measurements.

The relays employed to switch the lamp display are provided with extra contacts to enable an external circuit to be made or broken at a pre-determined count in the range of 0 to 999 999 and two terminals are fitted on the front panel to bring out the connexions. In addition to an output signal in the form of a narrow pulse at every millionth count is available from an output plug.

Airmec Ltd,
High Wycombe,
Buckinghamshire.

Microwave Spectrum Analyser

(Illustrated below)

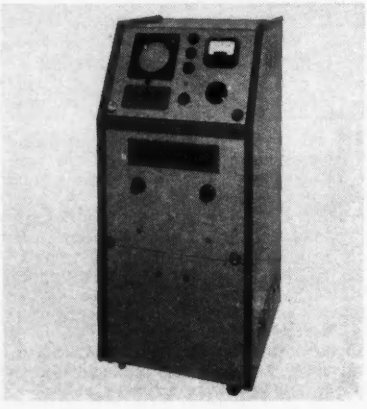
THE Racal spectrum analyzer type SA.18 is designed to give direct visual indication of the energy distribution of r.f. signals over the frequency range of 2 000 to 4 000 Mc/s.

A feature of the analyzer is that it utilizes a new type oscillator valve known as the "Carcinotron." This valve is basically a microwave oscillator of the backward wave type combining the principles and advantages of the magnetron and the travelling wave amplifier. Its most important characteristic is that its exceptionally wide tuning range is covered solely by varying the h.t. volts applied to the line electrode. No mechanical tuning is required.

In this instrument the Carcinotron is employed as a local oscillator the output of which is mixed with the input signal in a low Q coaxial line mixer. The signal is then taken through a variable precision attenuator to the i.f. stages, detected and after video amplification fed to the Y plates of a cathode-ray tube.

The centre frequency of the Carcinotron is determined by adjustment of the h.t. voltage and sweeping of the frequency is achieved by applying the sawtooth time-base voltage, via a series regulating valve to the line voltage. The steady voltage is displayed on a meter which is calibrated to show the centre operating frequency.

The visual display is presented on a 6in cathode-ray tube which is situated together with a line voltage meter, showing frequency, and time-base and tuning controls on the sloping upper panel. The lower panel carries the controls and meters for adjusting and monitoring the Carcinotron power supplies.



Racal Ltd,
Western Road,
Bracknell,
Berkshire.

Moving-coil Relays

(Illustrated below)

THIS type of relay, which is extremely sensitive and positive in operation may be used for a wide variety of purposes. It is particularly useful where a close differential between operating and resetting values is desired. The movement is of the conventional d'Arsonval type.

Besides a normal pointer, the moving-coil carries a light contact arm, which, on reaching the setting value, makes contact with a high or low fixed contact. The latter are movable over the scale in order to adjust the setting value.

In order to relieve the contacts from heavy duties which might have an adverse effect on the relay sensitivity, one or more "slave" relays are mounted in the relay case.

These relays are available designed for a number of applications and in a wide range of sensitivities.

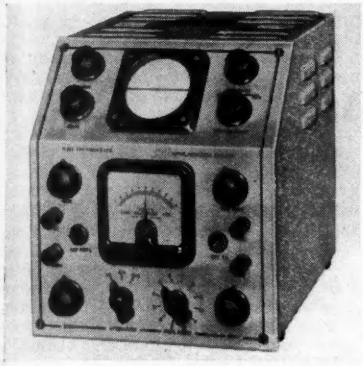
The Record Electrical Co. Ltd,
Broadheath,
Altrincham,
Cheshire.

Measuring Oscilloscope

(Illustrated above right)

THE type WM.I oscilloscope is a compact general purpose instrument provided with d.c. coupled amplifiers.

Voltage measurements are carried out



by means of a circuit unique to E.M.I. oscilloscopes. A displayed waveform or a selected portion can be expanded (with the unwanted parts excluded) and measured on the voltmeter. In addition, voltages may be measured relative to points above or below earth potential. This is invaluable when servicing a.c.-d.c. equipments. The time-base locks accurately to multiples or sub-multiples of the scanning waveform and the synchronizing signals may be derived either internally or from an external source. External signals may be used for the horizontal scan and are symmetrically fed to the c.r.t. X plates.

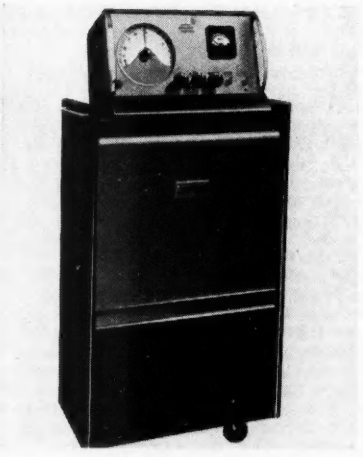
The range of voltage measurements covered is from 0·2 to 500V a.c. and d.c.; the deflexion sensitivity is 1cm/V and the maximum bandwidth is 3Mc/s. Time-base frequencies extend from 3c/s to 120kc/s and a saw-tooth of amplitude 160 to 200V is available for use with other apparatus.

E.M.I. Electronics Ltd,
Hayes,
Middlesex.

Power Oscillator

(Illustrated below)

THE model D120 power oscillator which provides a power output of 120 watts over a wide frequency range has been designed for use with the Goodmans vibration generator model 390A, where appreciable power is required for forced vibration excitation.



The unit is a complete drive equipment consisting of an oscillator and power amplifier with its associated power supplies contained in a mobile console cabinet.

The frequency range is 10c/s to 10 kc/s in three ranges; calibration accuracy is ± 2 per cent; hum level is − 70db; and distortion less than 2 per cent.

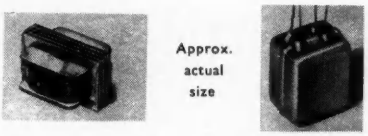
Goodmans Industries Ltd,
Axiom Works,
Wembley,
Middlesex.

Transistor Transformers

(Illustrated below)

BELCLERE type F transformers have been designed for use in transistor circuits, the size of these units being 17/32 by 7/16 by 5/16in. Five standard types covering input, interstage and output requirements are available and special types can be wound to order. The transformers can be supplied either open or mounted in mumetal screening cans.

John Bell and Croyden,
117, High Street,
Oxford.



Aluminium Soldering Tool

(Illustrated above)

THE Belark soldering tool is designed to overcome the difficulties encountered in making soldered connexions to aluminium.

A small steel wire-brush located in the solder-bit vibrates and cleans the surface by mechanical means. A pool of molten solder around the solder-bit protects the spot from air, which would otherwise oxidize again immediately. As soon as the oxide film is broken up, the molten solder tins the surface. The joining operation can then be finalized either with the same tool or by any appropriate method.

The heating element is directly connected to the mains while the vibrator is controlled by a trigger.

The Belark Tool & Stamping Co. Ltd,
33, Sussex Place,
London, W.2.

"Vitricon" Capacitors

"VITRICON" capacitors have a dielectric material and a protective material consisting of vitreous glazes, which are fired on to the copper plates at very high temperature. No organic materials are used in the construction, and they are therefore capable of operating at high ambient temperatures. The electrical properties are also satisfactory at high temperatures, the insulation resistance being maintained in excess of $10^{10}\Omega$ at an ambient temperature of 150°C.

The composition of the dielectric glaze may be varied in order to provide a selected value of temperature coefficient, anywhere in the range of 400 parts per million/°C negative, to 120 parts per million/°C positive. The capacitors are manufactured in styles having the terminals integral with the copper plates, or wire terminals welded to the plates.

At normal ambient temperatures, the insulation resistance is better than $10^{12}\Omega$ and the upper working temperature is 200°C. At present, the capacitors are being made in three miniature sizes, the largest of which is 0·64in. × 0·42in × 0·15in and having a maximum value of 400pF.

Metal Film Resistors

IN these hermetically sealed metal film resistors the resistive element comprises a noble metal alloy, burned into the surface of a glass tube. A helix is cut in this film, thereby increasing the aspect ratio considerably and enabling the resistors to be made to a close tolerance. The element is mounted within a second glass tube, and both are soldered into metal caps hermetically sealing the space containing the film. The resistors have a stability comparable with the best wire wound resistors, but have the advantage of offering considerably higher resistance values in a given size. The size at present being produced, which is 1⅛in long × ¼in diameter, is available in values from 1kΩ to 1MΩ. The stability is better than 0·05 per cent.

The temperature coefficient is dependent on resistance value, and is between 300 parts per million/°C and 360 parts per million/°C positive, higher values having the lower coefficient.

The size of resistor mentioned above is rated at 1 watt, and since there is no voltage limitation of the component, it is capable of the maximum dissipation in the highest resistance values.

Welwyn Electrical Laboratories Ltd,
Bedlington,
Northumberland.

Process Timers

THE range of electronic process timers now standardized by Hilton, have several interesting features. A predetermined voltage attained across a capacitor fed from a d.c. source through adjustable resistors calibrated in time, is detected by a cold cathode gas discharge triode. The triode, at the expiration of the time set on the two dials, fires, and a pulse of current is passed through a "pilot" relay which controls the main a.c. power relay. The main relay, in addition to carrying "work" contacts capable of switching 10A at 440V a.c., is fitted with auxiliary contacts for hold on and for switching the timing circuit.

The range includes timers designed for push button starting and for starting by the sustained closing of a pair of contacts. Provision is made for linking two or more timers to operate automatically in sequence with or without self cycling.

Hilton Electric Co. Ltd,
52, Pool Street,
Wolverhampton.

Short News Items

The Seventh British Electrical Power Convention will be held at The Dome, Brighton, from 27 June-1 July. The president of the convention is Sir Harry Railing, chairman and managing director, General Electric Co Ltd, and the vice-president is Sir John Dalton, chairman, W. T. Henley's Telegraph Works Co Ltd.

The 11th annual meeting of the American Institute of Navigation will be held at Montgomery, Alabama, from 23-25 June. Presentations will cover theoretical and practical aspects of civil and military navigation.

The Radio Component Show, held recently at Grosvenor House, London, was visited in three days by more than 20,000, including visitors from twenty-three foreign countries.

A Silicones for Industry Exhibition will be held in Manchester at the Midland Hotel from Monday, 13 June, to Saturday, 18 June. Invitations to the exhibition can be obtained on request from Midland Silicones Ltd, 19 Upper Brook Street, London, W.1.

The School of Engineering, Burnbank, Hamilton, Lanarkshire, recently staged an exhibition of electronic equipment which was patronized by some twenty-six firms.

A new mobile Decca Radar Unit has left London on a tour of all the ports of the United Kingdom and will be returning to London towards the end of September. This new unit consists of a specially constructed caravan equipped with the Decca 212 having ample space to accommodate up to ten people at a time in comfort. The caravan is hauled by a Land Rover specially fitted with a 5kW generator driven from the main engine which provides the power to drive the radar alternator, also fitted in the Land Rover, and all other electrical services.

On 25 April, 1955, the total number of ships of all classes for which Decca radar has been ordered exceeded 4 000.

E.M.I. Ltd announce that their trainees in this year's Physical Society Craftsmanship and Draughtsmanship Competition scored outstanding successes, being awarded the 1st, 2nd and 3rd prizes in the Class VI, Senior Grade. The judging was made from 130 selected entries in this nation-wide competition which included 21 organizations such as the radio, electrical and motor industries, the National Coal Board, British Electricity Authority, British Railways, six schools and one training centre.

The College of Technology, Birmingham, recently held a Diamond Jubilee Year Associateship Presentation ceremony at the Town Hall, Birmingham. The occasion was for the conferment of Honorary Associateships of the College on five men who have risen to control some of the largest industrial organizations in Great Britain, and the awarding of Associateships of the College of Technology to 128 men and women working in Midland industry who have completed to high standards schemes of advanced study in the several departments of the College.

Gresham Transformers Ltd, on extending their manufacturing capacity, have transferred the production of small transformers for the Electronics Division to their Lion Works on Hanworth Trading Estate, Feltham. Mr. K. G. Lockyer has been appointed manager of Lion Works. He was formerly production manager with Solartron Laboratory Instruments, having previously been with Philips (Mitcham Works) Ltd, Plessey, and London Electrical Co Ltd.

Cable & Wireless Ltd announce the opening of a new direct multi-channel v.h.f. radiotelephone service between Gibraltar and Tangier. Prior to the new service being inaugurated, telephone communication across the Straits of Gibraltar to Tangier could only be offered by a landline and cable route, by way of Spain. The improved facilities now offered will reduce the cost of calls to 5s. for three minutes.

Dowty Nucleonics Ltd has been registered as the new trade name and title of the firm Davis, Wynn & Andrews, pioneers in the development of instruments used in electronics, recently acquired by the Dowty Group. The new company represents an important and far-reaching addition to the Dowty interests, which already include aircraft, agriculture and coal mines. The organization will now be in a position to participate in important new fields of development and in line with the recent Government announcement regarding the future development of atomic energy.

Electran Coil Winding & Transformer Co Ltd, following on recent changes in management and reorganization of staff, announce a reduction in the price of radio transformers and chokes. The current catalogue is available and there is an open invitation to visitors who would care to inspect the works at Lichfield Road, Aston, Birmingham, 6.

The Radio Industry Council announces that the first of the students who entered three-year technical training courses started in 1952 are now about to enter the radio industry. The courses were organized by the Ministry of Education, following consideration of training problems by the Radio Industry Council's Technical Training Committee and the Radar Sub-Committee of Lord Hankey's Technical Personnel Committee, at five London and provincial centres. The object of the courses is to provide students so well trained in the theory and practice of electronics that they will be able, on completion, to take their places at once as assistants to qualified research and development engineers.

Aero Research Ltd, Duxford, Cambridge, were visited by H.R.H. The Duke of Edinburgh on the occasion of a special display commemorating their twenty-first anniversary.

The General Electric Co Ltd has supplied the equipment for another microwave radio television link in Switzerland. It connects Uetliberg (Zurich) with La Dole (Geneva) and on the way ties in with the trans-Alpine Chasseral-Monte Generoso link, which was supplied by the G.E.C. twelve months ago for the Eurovision exchange of programmes. The new link forms part of a television network which will cover most of Switzerland. It was installed by Hasler S.A. on behalf of the Swiss Post, Telegraph and Telephone Administration.

The 15MeV Accelerator for radiotherapy and radiobiological research which was designed and constructed by Mullard Ltd, and described in the December, 1954, issue, has now been installed at St. Bartholomew's Hospital. The president, His Royal Highness The Duke of Gloucester, recently performed the official opening ceremony.

The BBC, as the result of a recent meeting with the Lieutenant-Governor's Advisory Committee on Broadcasting in the Isle of Man, has now decided its plans for the future development of television and sound broadcasting for the island. The temporary television transmitter at Carnane, near Douglas, is giving a satisfactory service to about 60 per cent of the island's population. In addition to this, a new permanent television station has been erected at Divis, near Belfast. This station is expected to begin operating in July of this year, and it is hoped that it will give a satisfactory service to viewers living in the North of the Isle of Man, provided they are favourably situated and use good aerials. This transmission from Divis,

together with the transmission from Carnane and also with the transmission already received in reasonable quality by viewers of Holme Moss direct, will mean that from the summer this year the majority of the population of the island should receive satisfactory service. Meanwhile, the BBC has been searching for a suitable site on which to erect a permanent television transmitter for coverage of the whole island. After considering and testing a number of alternative proposals, it became obvious that the summit of Snaefell would give an entirely satisfactory service to the island as a whole. The Ministry of Transport and Civil Aviation, for reasons of safety of life, was not prepared to grant permission for such a station to be erected unless the BBC could demonstrate by tests that no interference would be caused to the Ministry's transmitting and receiving station which is already operating on Snaefell. For reasons of geography, and other commitments, these tests cannot take place until early summer 1956. The Ministry also reserves the right to close down the transmitters temporarily should the safety of aircraft be in danger. However, the BBC confidently hopes to begin the erection of the permanent television transmitter on the Snaefell site immediately after the necessary tests have been carried out. At the same time, in order to improve the island's sound broadcasting reception, the BBC proposes, subject to Post Office approval, to incorporate three v.h.f./f.m. transmitters in the Snaefell site.

The Post Office announce that two sets of regulations come into force on 1 September giving the Postmaster-General power to control interference with radio (including television) from refrigerators, and from domestic and industrial appliances which are driven by small electric motors. The regulations lay down the requirements which must be complied with by manufacturers, assemblers, and importers of all electrical refrigerators and by users of new and old electric motors. These arrangements were recommended by the Advisory Committees appointed under Section 9 of the Wireless Telegraphy Act 1949, and the regulations have been drawn up with the agreement of these Committees.

The Societe Belge de Physique held its annual general meeting recently and the following officers were elected. President, Professor P. Wings; Vice-Presidents, Professors W. de Kryzer, J. Delfosse and G. A. Homes. The Secretary-General is Dr. M. C. Desirant and the address of the Secretarial Office is A.C.E.C. Physics Research Laboratory, Charleroi, Belgium.

Crane Packing Ltd., of Slough, a member of the Tube Investment Group of Companies, has just completed the design and construction, in their own works, of special plant and equipment for the extrusion in substantial quantities, to exact and uniform standards of quality, of the plastic polymer Polytetrafluoroethylene (PTFE).

Pye Ltd announce that the largest television outside broadcast van yet produced by them recently left their Cambridge factory bound for Bayerischer Rundfunk, the Bavarian State Broadcasting Station in Munich. The van has provision for three camera chains, as well as standby equipment to enable it to work independently of the main station. Space has been left in it for special German sound equipment and tape recording machines.

At the annual general meeting of the British Radio Equipment Manufacturers' Association, Mr. M. M. Macqueen was re-elected chairman. No vice-chairman was elected and the existing Council was re-elected without change.

The Portuguese Civil Aviation Authorities have purchased from International Aeradio Ltd the basic units of an Air Traffic Control Trainer capable of application for aerodrome approach and airways training. The equipment will be installed at Portela Airport, Lisbon.

Sydney S. Bird & Sons Ltd announce that their works have now removed to Fleets Lane, Poole, Dorset. Telephone Poole 1640. The London sales office is now at 3 Palace Mansions, Palace Gardens, Enfield, Middlesex.

Atkins, Robertson & Whiteford Ltd, 92/100 Torrisdale Street, Glasgow, S.2, have opened a London office and showroom at 53 Victoria Street, London, S.W.1, to deal with the inquiries from London and the South for transformers and electronic instruments.

Armstrong Wireless & Television Co announce the appointment of three of their senior staff to the Board of Directors. They are Mr. A. Adams (Sales Manager), Mr. T. Nikolin (Production Manager), and Mr. G. Tillett (Chief Engineer).

The Solartron Electronic Group Ltd., announce that Mr. Bowman Scott. M.B.E., has been elected a Member of the Board. Mr. Scott, who joined the Company from Urwick, Orr & Partners, will continue his duties as Personnel and Training Officer for the Group and will also be concerned closely with Group organization and policy.

Harwin Engineers Ltd. have recently acquired additional premises at Uxbridge, Middlesex, to be devoted to increased production of Terminal Lugs. All sales and technical inquiries should continue to be addressed to 101-105 Nibthwaite Road, Harrow; telephone: Harrow 0381. Mr. D. D. Windram has been appointed General Works Manager to the company.

Erratum. In the letter entitled "A Versatile Pulse Shaper" which appeared on p. 188 of the April issue, for ". . . delays up to 1·5Mc/s" read ". . . delays up to 1·5μsecs".

PUBLICATIONS RECEIVED

APPLIED RESEARCH IN ELECTRICAL ENGINEERING is a summary of this research in progress in university colleges and technical colleges in London and the Home Counties. The summary has now been prepared for the seventh year in succession and copies may be obtained from the Secretary, Regional Advisory Council for Higher Technological Education, London and Home Counties, Tavistock House South, Tavistock Square, London, W.C.1.

C.M.A. RUBBER AND THERMOPLASTIC INSULATED CABLES is the subject of a recent brochure produced by Enfield Cables Ltd, Victoria House, Southampton Row, London, W.C.1.

SINGLE SIDEBAND FOR THE RADIO AMATEUR prepared by the Headquarters staff of the American Radio Relay League is a comprehensive digest of articles on the subject, revised in line with current practice. There are over 300 illustrations, including charts, tables and formulae. American Radio Relay League Inc., Administrative Headquarters, West Hartford 7, Connecticut, U.S.A. Price $1.50 in the United States, $1.75 elsewhere.

SOME RECENT ADVANCES IN TINPLATE MANUFACTURING PROCESSES by W. E. Hoare is a reprint of an address given at the 9th International Congress on Packaging held at Parma, Italy, in September, 1954. The paper is a review of the present stage of development of tinplate manufacturing methods. Tin Research Institute, Fraser Road, Perivale, Middlesex.

THE 1955 MARCONI INSTRUMENTS CATALOGUE OF TELECOMMUNICATION MEASUREMENT EQUIPMENT AND INDUSTRIAL ELECTRONIC INSTRUMENTS is available to senior engineers and executives, on request. This publication contains sections on frequency measurement, voltage and power measurement, distortion measurement, transmission measurement, signal generators and accessories, oscillators and accessories, bridges and Q meters, television and radar test equipment, pH measurement, moisture measurement, and industrial X-ray apparatus. The instruments are indexed both alphabetically and by type number. Marconi Instruments Ltd, St. Albans, Hertfordshire.

WIRELESS AND ELECTRICAL TRADER YEAR BOOK 1955. A valuable new feature of this 26th edition is the special section giving both alphabetical and territorial lists of radio and electrical wholesalers in which association members are indicated, while the complete text of the wages agreement covering radio and television service engineers together with wage rates and details of the rates of pay of radio and television shop managers and assistants, is again included. Other data includes specifications of current radio receivers covering over 250 models, legal and licensing information and a directory of trade associations. Trader Publishing Co. Ltd, Dorset House, Stamford Street, London, S.E.1. Price 12s. 6d.

PAYMENT SECURED gives a brief description of the work undertaken by the Exports Credits Guarantee Department, 9 Clements Lane, Lombard Street, London, E.C.4.

INSTRUMENTS FOR ELECTRICAL, ACOUSTICAL, RADIOACTIVE, VIBRATIONAL, STRAIN GAUGE and ELECTRO CHEMICAL MEASUREMENTS is the subject of a catalogue produced by the Danish company Bruel and Kjaer, for whom Rocke International Ltd act as their London office. This range of electronic equipment is imported in quite large numbers. Rocke International Ltd, 59 Union Street, London, S.E.1.

VALVES FOR A.F. AMPLIFIERS is a booklet in the Philips' Technical Library series and shows the radio designer and amateur setmaker how to build amplifiers. Cleaver-Hume Press Ltd, 31 Wrights Lane, London, W.8. Price 10s. 6d.

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

An Electromechanical Current Stabilizer for an Electrolytic Cell

DEAR SIR,—We have recently found a need to stabilize the current through an electrolytic cell running at a current of 1A with a p.d. of about 5 to 10V. A coulometer is not suitable for measuring a current of this magnitude and since the resistance of the cell tends to fluctuate during an electrolysis, automatic current stabilization is necessary so that the quantity of electricity passed can be estimated from the time occupied by the run.

Many of the d.c. current stabilizers previously reported in the literature are unsuitable for our purpose as they produce much smaller currents than we required. Others giving the necessary power employ gas-filled valves which we did not possess. We have, therefore, designed and built an electromechanical controller using only parts readily available in most research laboratories, which will give a continuously variable controlled d.c. output of up to 2A. The stability has been checked by a recording meter and is about $\pm 0{\cdot}2$ per cent at 1A. With slight modifications much larger controlled currents could be obtained.

The circuit is shown in Figs. 1 and 2. It is essentially a balanced 2-stage push-pull d.c. amplifier. Through a relay system this operates a reversible 24V motor, mechanically coupled by a worm gear to a Variac supplying the power transformer and rectifier. The operating voltage is obtained across the variable control resistor VR_3 which is in series with the electrolytic cell or cells; making this resistor variable enables us to set the magnitude of the stabilized current. If VR_3 is varied or if the current through it varies, the voltage change is reflected in a change of potential between the anodes of V_3 and V_4, between which is connected relay *A*, a polarized micro-armature changeover relay. This relay is the heart of the controller and operates on 25μA; in turn it energizes one or the other of two P.O. type relays *B* or *C* feeding the reversible motor. The connexions are such that the Variac is driven in the sense which tends to produce zero voltage across relay *A*.

If an open-circuit develops in the cell line or if the resistance of a cell rises beyond the controlling range of the circuit, relay *B* will close and the controller will drive the Variac up to its maximum setting. In order to avoid damage a fourth relay, *D*, is provided which is energized through the mechanically operated microswitch S_2 to cut the power to the motor when the Variac setting reaches some arbitrary value, in our case 220V. (Switch S_2 is normally shut). With this simple arrangement however, when this point is reached the controller is no longer capable of re-setting itself when the cell circuit is re-made or the resistance reduced. To avoid the need for mechanical re-setting, S_2 is connected across an extra pair of contacts on relay *C* (which is used to drive the Variac to lower settings). On remaking the circuit, relay *B* opens and relay *C* closes: S_2 is thus shorted out and the motor can operate again. As soon as the Variac

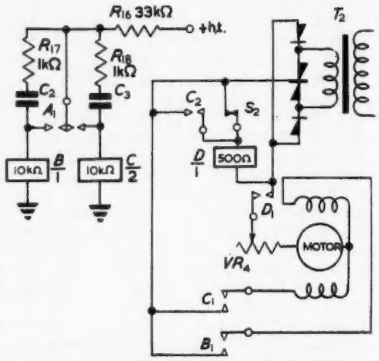


Fig. 2. Reversible Aircraft Antenna Motor (U.S. surplus equipment). G.E. type BA 24V 5·5A Fitted with magnetic clutch and reduction gear

setting falls below 220V, S_2 closes again and the operation becomes normal.

The sensitivity of the instrument is such that with the motor running at full speed the overshoot causes hunting, even with the mechanical reduction of 130 to 1 provided by the worm gear. To avoid this it is necessary to reduce the voltage supplied to the control motor, by means of the variable resistor VR_2. It may also be necessary to connect a small capacitor, say 0·1μF, between the anodes of V_1 and V_2. By being able to vary the voltage, the control point can be approached rapidly when setting the control to a particular value. The voltage across relay *A* may be appreciable when the instrument is off balance at the start of a run but the overload permitted on this relay is sufficient to prevent any damage on this account. The controller will operate with a minimum of 5V input. It can therefore, be run at currents greater or smaller than 1A if there is sufficient range to VR_2 and if there is sufficient output voltage available. By increasing the ratings of the output transformer and rectifier the controlled power can be greatly increased.

This note is published by permission of the Director.

Yours faithfully,

J. A. MORRIS,
R. B. TEMPLE,

Chemical Research Laboratory,
Teddington.

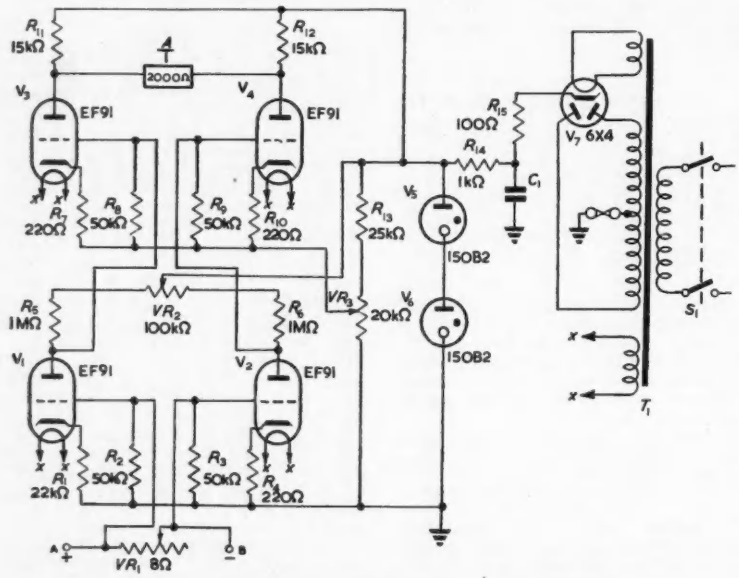
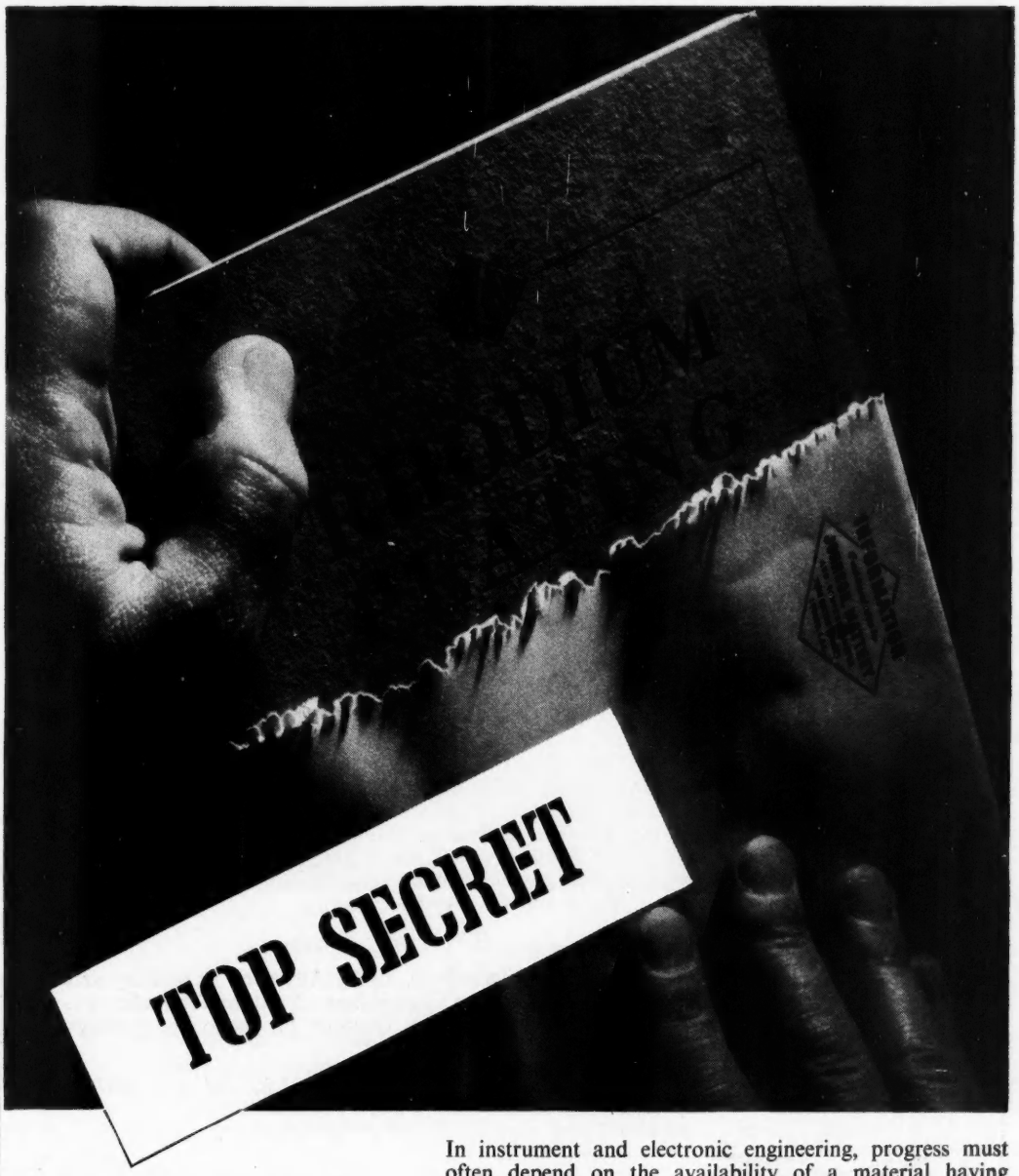


Fig. 1. Circuit showing a balanced 2-stage d.c. amplifier



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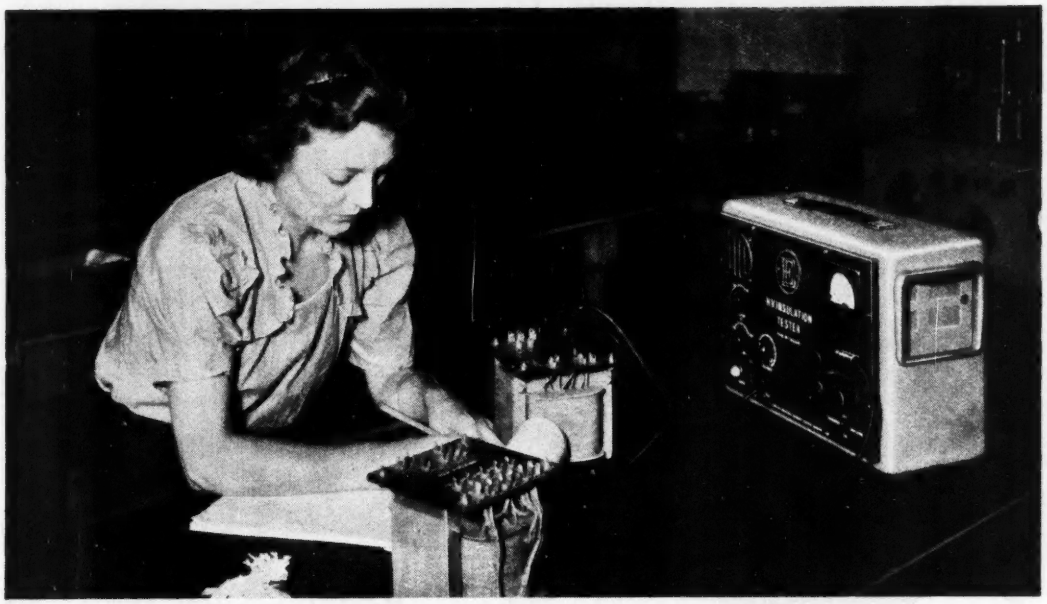

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This photograph shows the tester being used to check the high voltage insulation of small transformers, one of the many jobs for which it is exactly suited.

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- No load to full load performance
- Excellent finish and fine workmanship throughout

Specification

RATING	1 KVA
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INPUT FREQUENCY	50 c/s±10%
OUTPUT VOLTAGE	220-240 (adjustable)
REGULATION ACCURACY	±0.1% nom.
RECOVERY TIME	0.1 secs.
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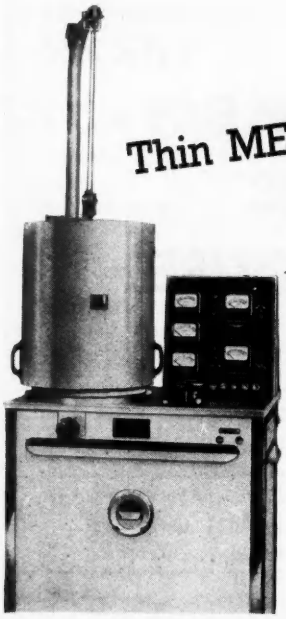

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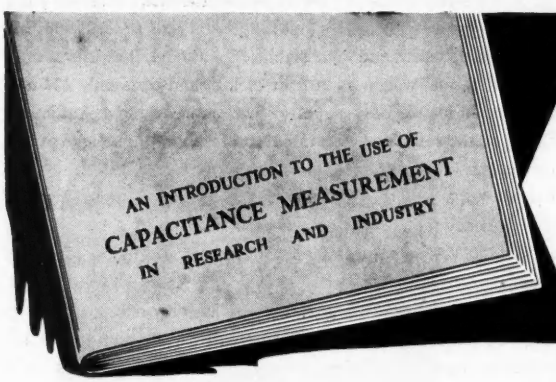
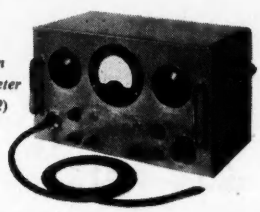


This 28 page booklet—

with sketches and data, which has been produced by our Technical Services Dept., was compiled as an aid to users of the Fielden Proximity Meter.

but we will gladly send a copy on request to any interested research worker.



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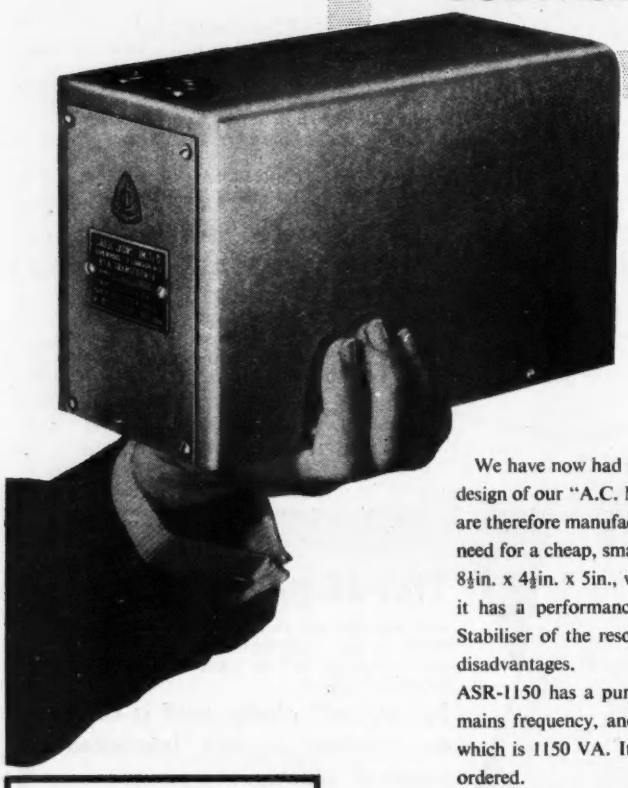

We have now had released to us by a Government Department the design of our "A.C. Mains Regulator, Automatic, Step, Mark II", and are therefore manufacturing this unit for general sale. It ideally fills the need for a cheap, small and light Stabiliser. Although it measures only 8½in. x 4½in. x 5in., weighs as little as 11 lbs., and costs only £24 net, it has a performance fully equal to any similarly rated Automatic Stabiliser of the resonated, saturated core type, without any of the disadvantages.

ASR-1150 has a pure output waveform, is unaffected by changes in mains frequency, and works equally well from no-load to full load, which is 1150 VA. It has a stabilised output at 230V unless otherwise ordered.

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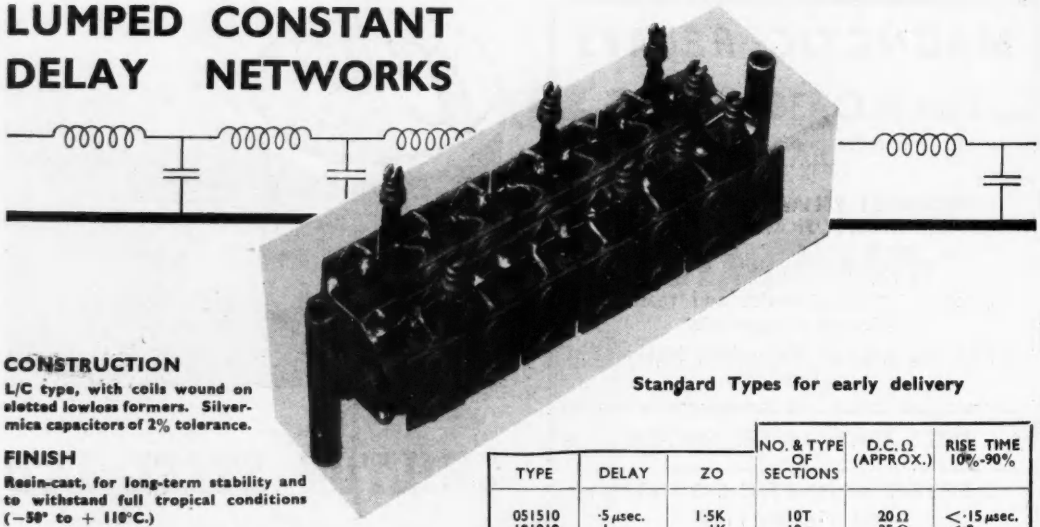

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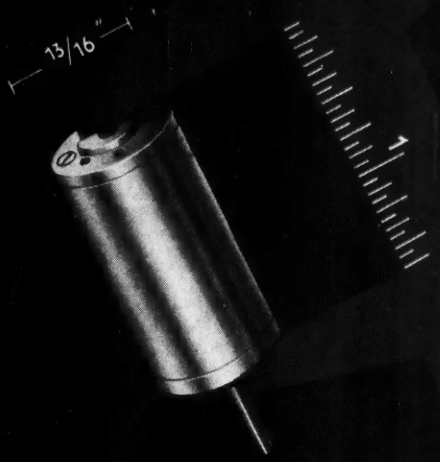

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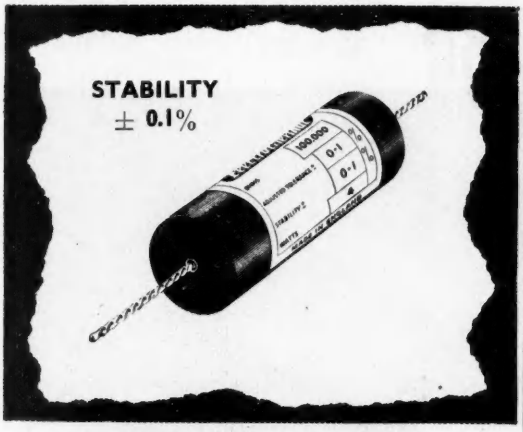

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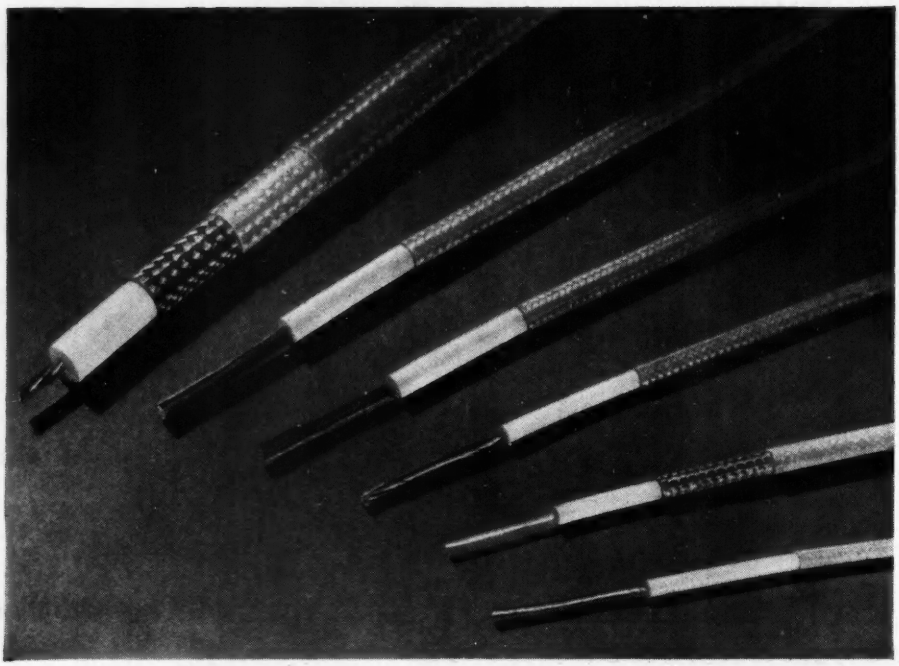

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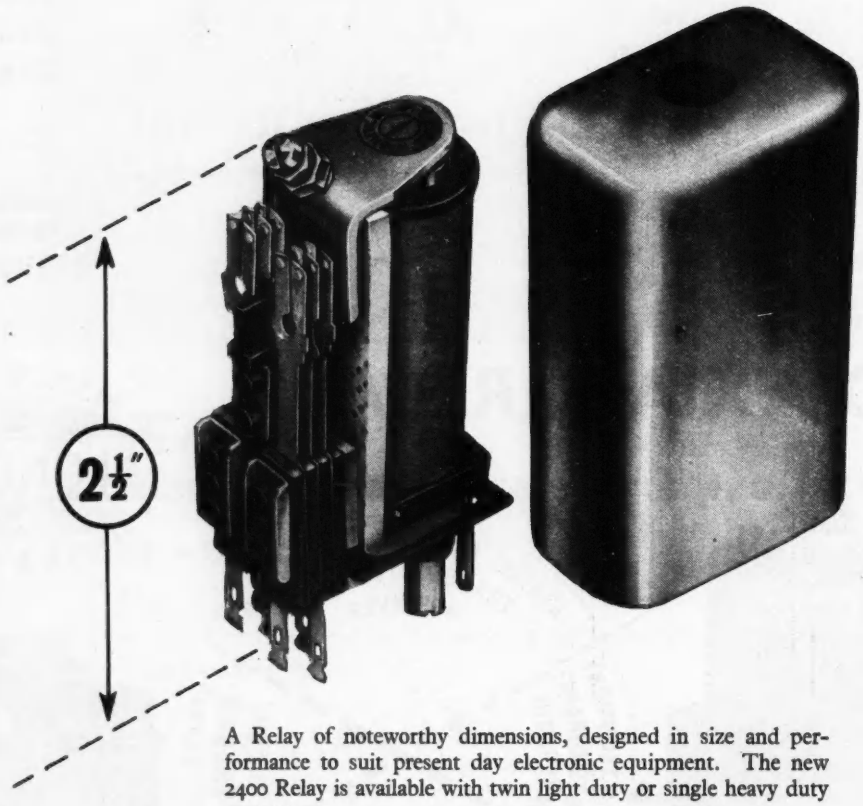

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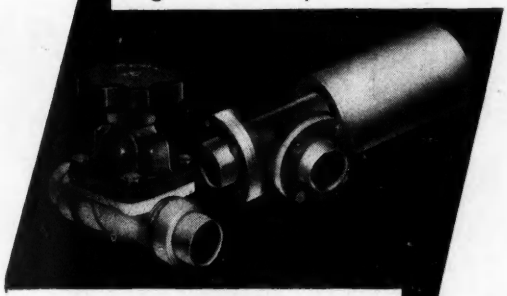

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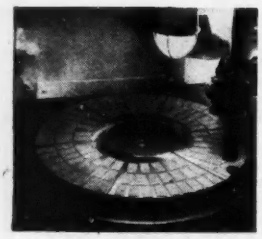

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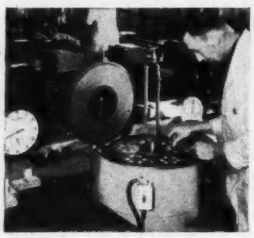
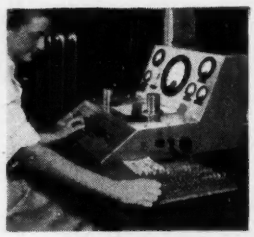
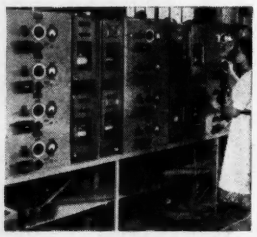


Planetary Lapping



Finishing to Frequency



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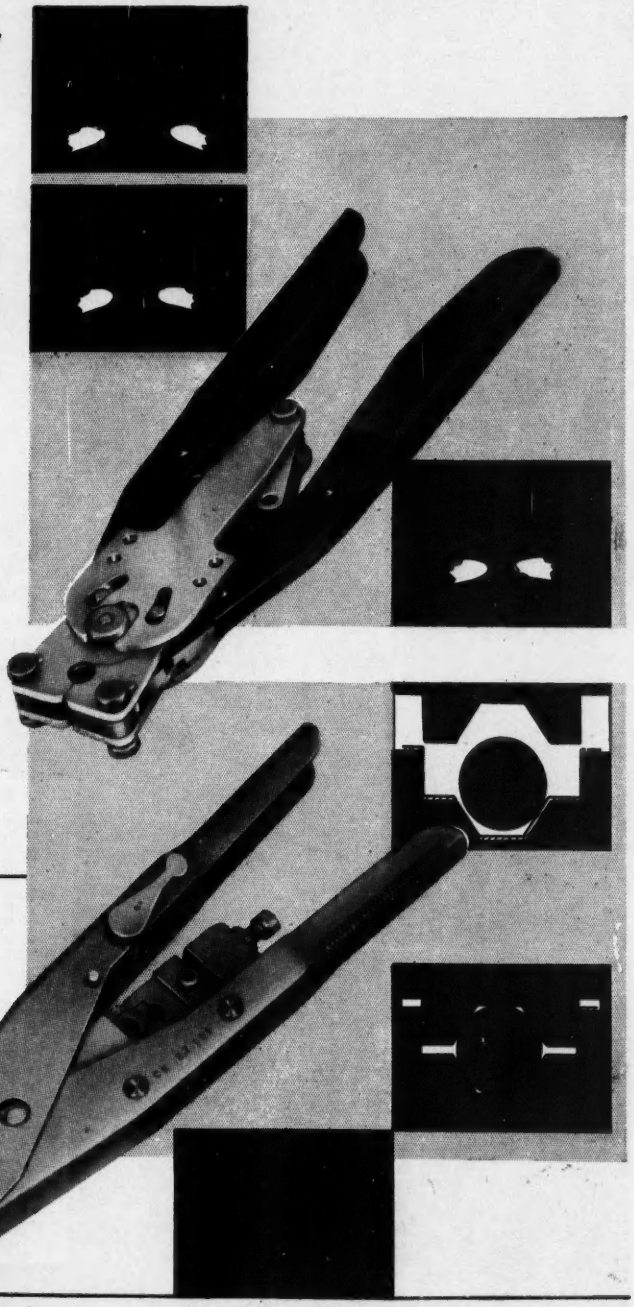

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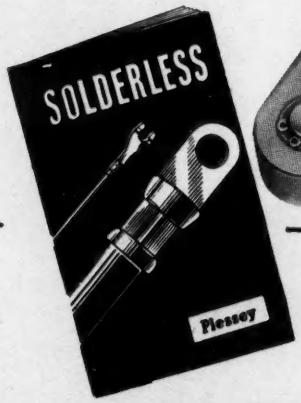

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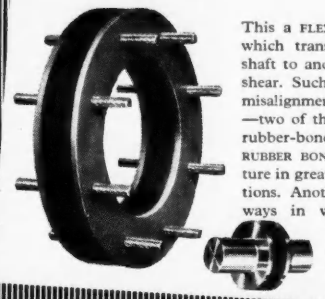

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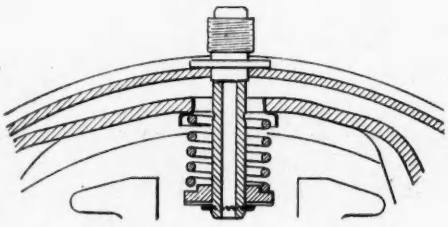

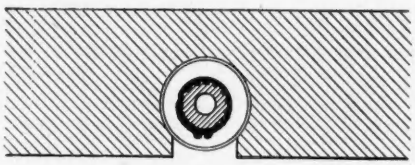

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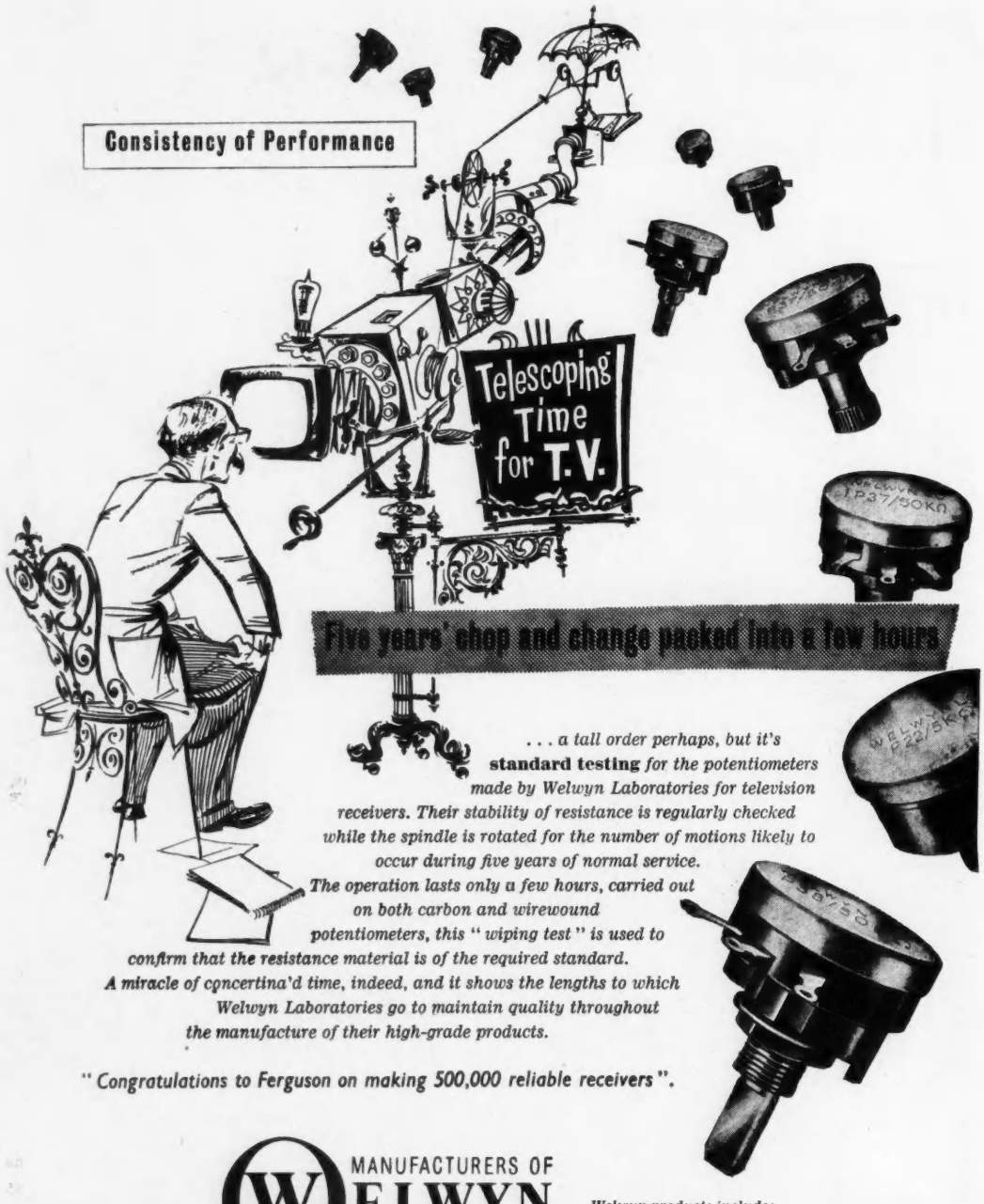

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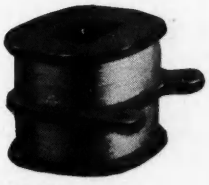

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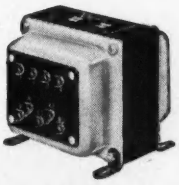

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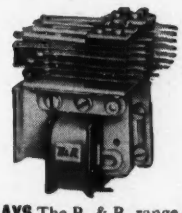
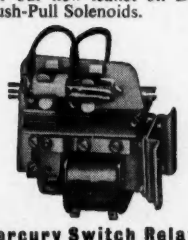
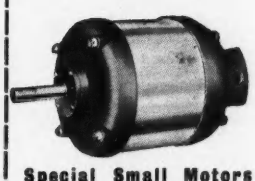


RELAYS The B. & R. range of Relays grows monthly. Their new factory at Harlow is nearly completed. Have you a catalogue of their latest Relay, the J.O.1., "A quart in a pint pot"?



Mercury Switch Relays B. & R. Mercury Switches are available, built for stock, at competitive prices, incorporating their patented designs. Have you a Mercury Switch leaflet?



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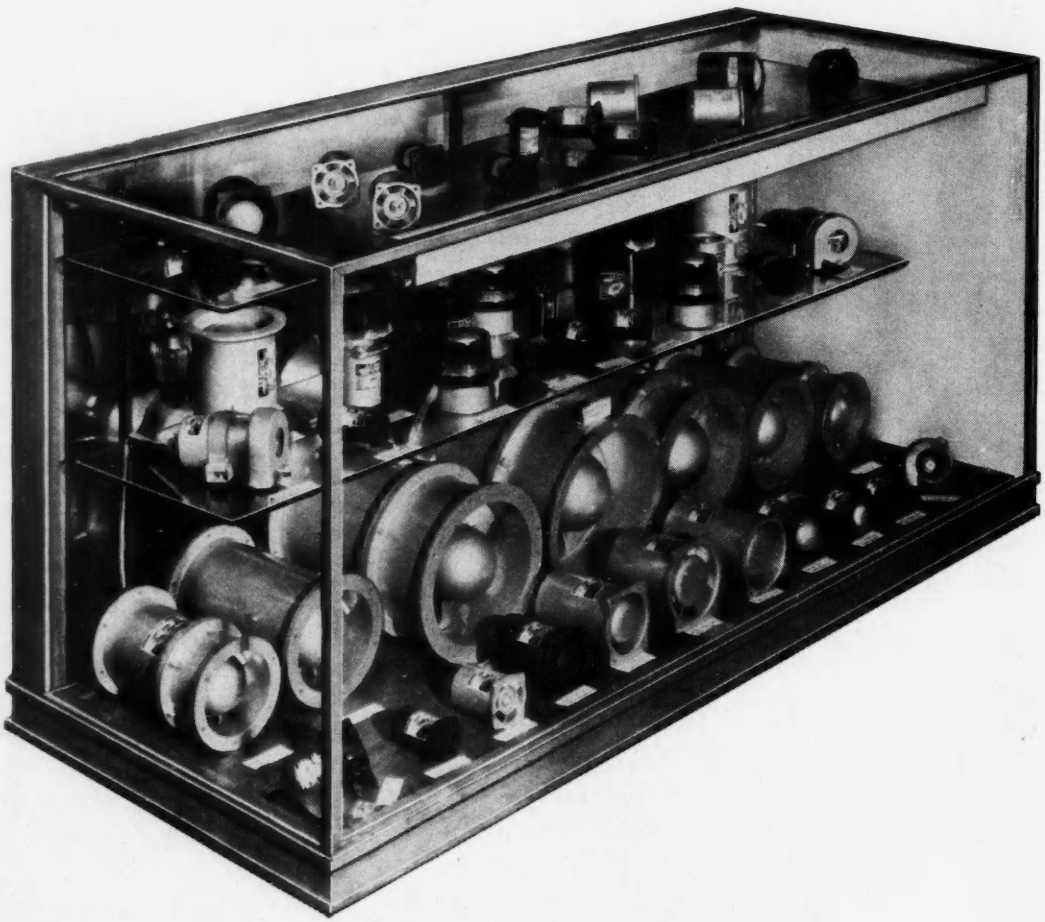

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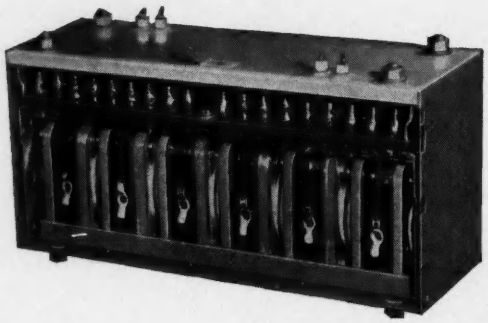
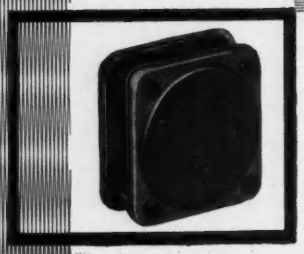
20th CENTURY ELECTRONICS LIMITED

Improved filter units





with Ferroxcube pot cores

1 *High performance combined with small size and light weight.*

2 *Designed and built to customers' individual requirements.*

3 *Long term stability, even under conditions of temperature variation.*

High quality electrical filter units built around Ferroxcube cores can now be supplied to communications equipment designers' individual specifications. These filter units have significant advantages over comparable types designed without the use of Ferroxcube, particularly in the frequency range 300 c/s to 500 kc/s. For audio frequencies the use of Ferroxcube cores permits the winding of compact coils with very high inductances. This results in a considerable reduction in the size and cost of the associated condensers and hence of the filter unit as a whole. The high Q values obtained for a given volume, especially above 10 kc/s, enable sharp cut off characteristics and low pass-band losses to be achieved, while negligible stray flux facilitates the production of compact and mechanically robust filters. Electrical filter units are among a number of high quality components now being made available by Mullard. Full details of the complete series of components will be gladly supplied upon request.

Mullard

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Magnadur ceramic magnets
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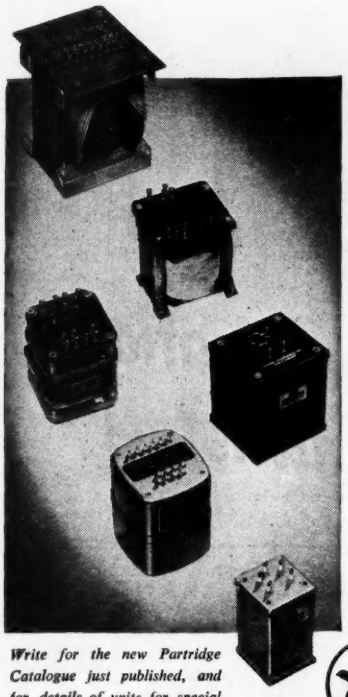

Write for the new Partridge Catalogue just published, and for details of units for special circuits.

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The Partridge Range of Transformers is such that there is a type to fulfil almost every replacement need, and deliveries are ex stock. Each is covered by a 12 months' guarantee. The range includes Power Transformers, single or multi-phase, up to 100 kVA ; all grades of audio frequency transformers ; "C" core transformers, etc.

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Many of the prominent amplifier circuits, including those published by the G.E.C. and Mullard Technical Departments, employ Partridge Transformers. Two examples are the Osram 912 High Quality Gramophone Amplifier, where Partridge Transformers and chokes were used in the prototype, and the Mullard 510 High Quality Amplifier which employs a Partridge Type PPO.

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Trustworthy for communications and Industry

Within the normal BRIMAR range there is now available a large number of types tested in accordance with the UNIQUE TRUSTWORTHY standard. This standard was, of course, primarily established to meet Services Requirements, in which extremes of resistance to shock and vibration are a vital factor. Such extremes are rarely called for in normal industrial use. But the fact that these valves have passed such an additional rigid test offers a very worthwhile 'bonus' in performance—specially for use in equipment required to operate for lengthy periods without attendance.

The accompanying table shows the complete range of Industrial "T" Valves, all of them available with reasonable delivery. In many instances additional types can be made available for special applications.

INDUSTRIAL T RANGE

T Code	Equivalent Commercial Type Code	Function	Base
6058	6AL5	Double Diode	B7G
G/6156	6AM5	Power Pentode	B7G
6064	6AM6/8D3	High Slope R.F. Pentode	B7G
G/6066	6AT6	Double Diode Triode	B7G
G/5749	6BA6	Vari Mu R.F. Pentode	B7G
G/5750	6BE6	Heptode Mixer	B7G
G/6059	6BR7	Low Noise A.F. Pentode	B9A
G/6061	6BW6	Output Beam Tetrode	B9A
G/6132	6CH6	Video Output Pentode	B9A
G/6100	6C4	Triode Amplifier	B7G
G/6180	6SN7GT	Low Mu Double Triode	Octal
6063	6X4	Full Wave Rectifier	B7G
6065	9D6	Vari Mu R.F. Pentode	B7G
G/6060	12AT7	High Slope Double Triode	B9A
6067	12AU7	Low Mu Double Triode	B9A
6057	12AX7	High Mu Double Triode	B9A
G/6158	13D3	Special Purpose Double Triode	B9A
G/6062	5763	V.H.F. Beam Tetrode	B9A
G/6157	R17	Half Wave Rectifier	B9A
G/6443	R18	Half Wave Rectifier	B9A
G/6L6GA	6L6GA	Output Beam Tetrode	Octal
G/25L6GT	25L6GT	Output Beam Tetrode	Octal
G/6042	25SN7GT	Low Mu Double Triode	Octal
G/50C5	50C5	Output Beam Tetrode	B7G

Notes : Type 6058 will be superseded eventually by Type 5726 (Short Bulb Version).

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EQUIPMENT

(A product of N. V. Philips Eindhoven)

Philips 'Unitised' nuclear radiation monitoring equipment can be supplied in separate units or in any combination, suitable housings being available for single, double or triple combinations. Thus any unit can be supplemented by other equipment when the scope of laboratory activities is extended.

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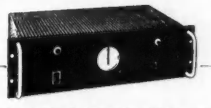
Sensitivity, 0.5V pk positive or negative.
Input Impedance, 1 m Ω.
Resolving Power, 0.5μ s for statistically distributed pulses.
Max. Counting Capacity, 4×10^5 — 1 counts.

HIGH VOLTAGE—PRE-AMPLIFIER UNIT PW4022

HIGH VOLTAGE SECTION:
Stabilised High Voltage, 0—2,500V DC in steps of 20V.
LINEAR AMPLIFIER SECTION:
Amplification, X 250 (Stepped Attenuator).
Bandwidth, 500 c/s to 3 MC/S (½ power value).
Max. Output Voltage, 10V.
Output Impedance, 3 K OHM.



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Provides facilities for pre-determined count techniques. Count numbers preselected by six position switch, viz, 10, 10^2, 10^3, 10^4, 10^5 with a "free" position to enable "Timed" counts to be made.
The times are directly recorded on a precision clock which is automatically stopped when the desired count number has been achieved.

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RIVLIN *precision* WIREWOUND RESISTORS

★ *American types reproduced.*

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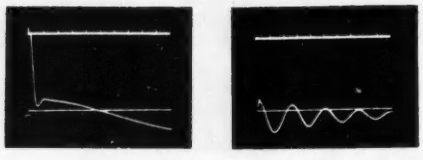
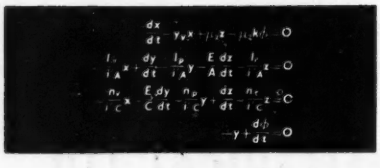
About the analogue computor

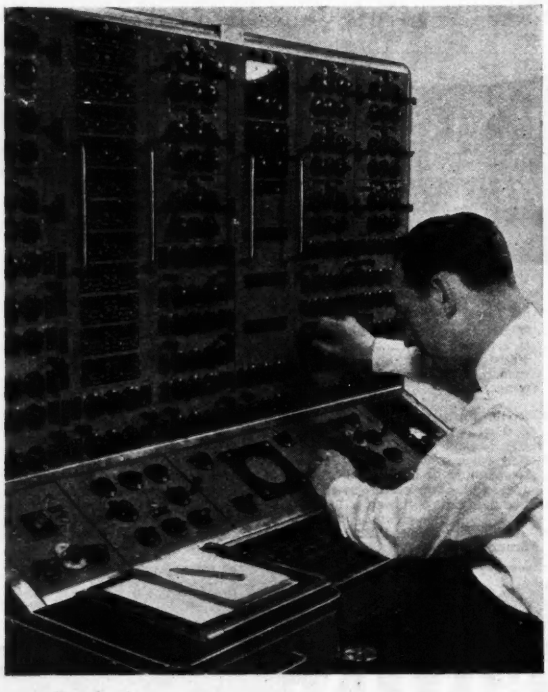
The electronic analogue computor makes patterns like this



which solve differential equations like these



IT RUNS THROUGH in a matter of hours a range of solutions that would take a team of mathematicians weeks to work out. You knew that? But did you know that Shorts are now making a general purpose analogue computor which can be harnessed, singly or in banks, to solve a wide variety of engineering problems? This, the first British analogue computor in production, will deal with linear or non-linear systems. Apart from the solution of differential equations, the instrument may be applied to the design of servo systems and to analysis and synthesis in connection with the behaviour and design of dynamic electrical, mechanical and thermal dynamic systems.
The Short Analogue Computor is described in a brochure which you will certainly find interesting and probably find profitable. A word to the address below and a copy will be sent to you.



In one day at the console, an operator can set up problems and get answers that would take weeks of expensive study by normal means.

Here's the *Short* answer

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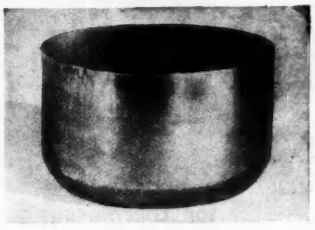

THESE TWO PHOTOGRAPHS ILLUSTRATE SIMILAR PRESSINGS MADE UNDER IDENTICAL CONDITIONS. THAT ON THE LEFT SHOWS THE PERFECT RESULTS OBTAINED WITH NARITE DIES, COMPARED WITH THE WASTER PRODUCED BY ORDINARY STEEL DIES.

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MORE PROFIT

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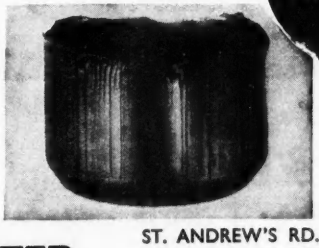

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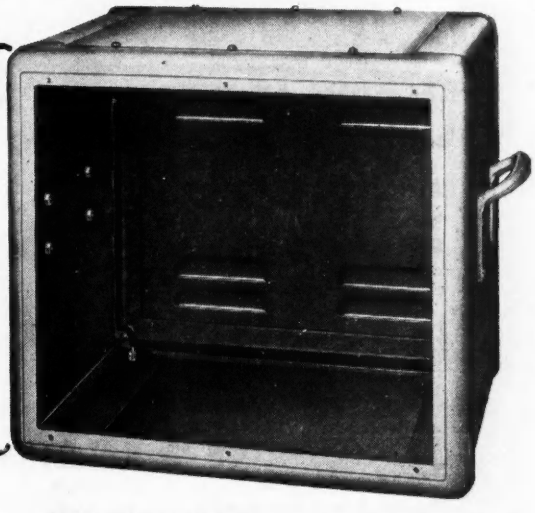

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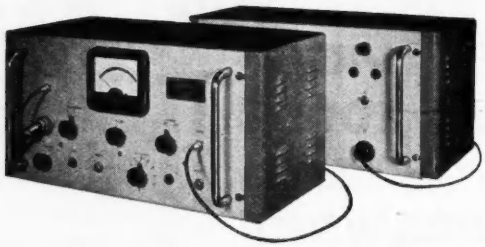

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TYPE P868

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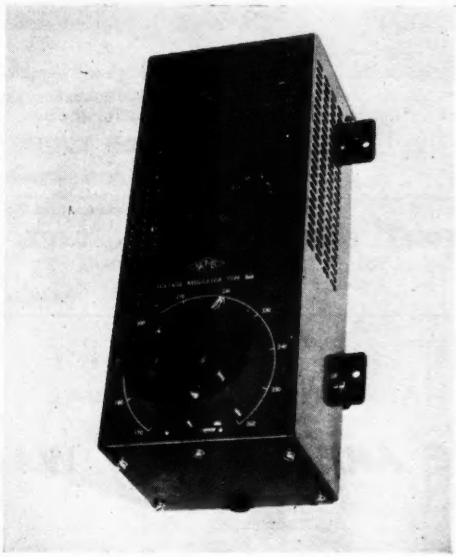

This regulator, together with the 5 kVA Automatic Voltage Regulator Type P857 and 750 VA Automatic Voltage Regulator Type P881, will be exhibited on our Stand No. 9F at the British Instrument Industries Exhibition, 28th June to 9th July.

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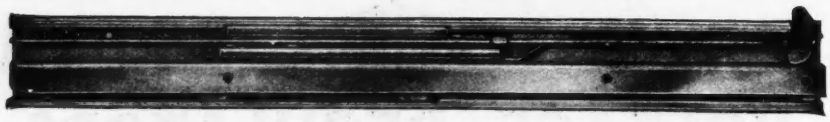

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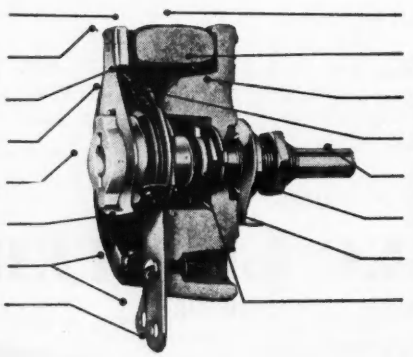

1 Silver graphite brush contact
2 Balance point for self-aligning brush
3 Pig tail shunting brush arm
4 Nickel silver brush arm
5 Glazed porcelain brush arm insulator
6 Winding welded to terminal band
7 End contact band and terminal
8 Brush terminal
9 Winding embedded in vitreous enamel
10 Vitreous enamel bond between former and base
11 All ceramic construction withstands 5000v. flash test
12 Non-grooving return contact plate
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16 Stop on shaft engages pressing in base moulding groove.

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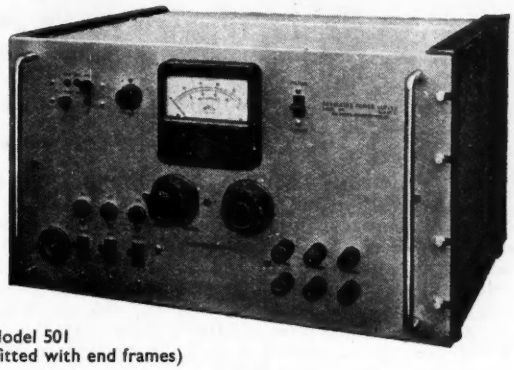

Model 501
(fitted with end frames)

ABRIDGED DATA

(Further information on request)

	Data	Model 501	Model 502	Model 503	Model 504	Model 505
MAIN +VE Stabilizer	Output	200-500V 250mA	200-500V 250mA	0-500V 250mA	0-500V 250mA	0-500V 150mA
	Number of Ranges	2	2	4	4	1
	Voltage Stabilization	±0.02%	±0.002%	±0.1%	±0.002%	±0.1%
	Effective Output Resistance (max.)	0.2 Ω	0.02 Ω	0.5 Ω	0.02 Ω	0.5 Ω
	Output Ripple (rms. max.)	2mV	1mV	3mV	1mV	3mV
—VE Supply Stabilizer	Outputs	—	—	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA
	Voltage Stabilization	—	—	±0.05%	±0.002%	±0.05%
	Output Resistance (max.)	—	—	1 Ω	0.01 Ω	1 Ω
	Output Ripple (rms. max.)	—	—	2mV	1mV	2mV
Unstabilized +VE H.T. Supply 250mA max.		470V 630V	470V 630V	320V 470V 630V	320V 470V 630V	630V
Unstabilized A.C. Supply		6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A
Price		**£70**	**£91**	**£81**	**£99**	**£75**

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OUTPUT IMPEDANCE .. 50 ohms
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ELECTRONICALLY STABILISED power supplies

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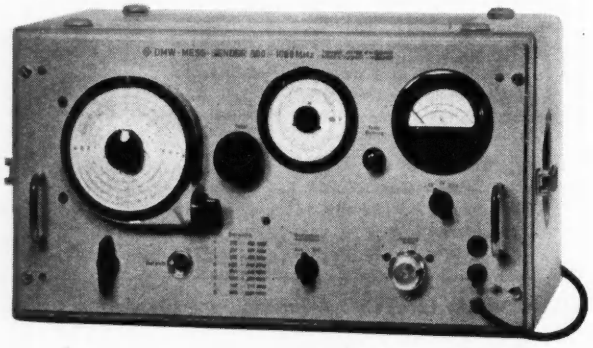

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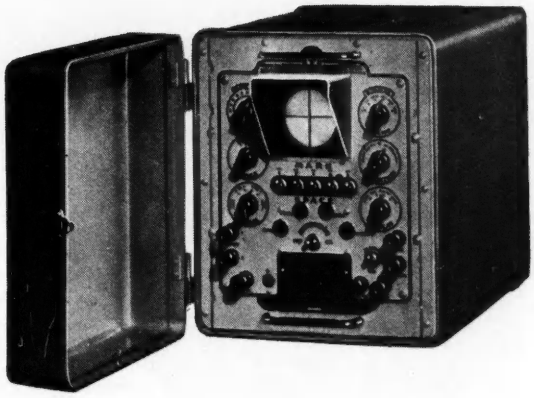

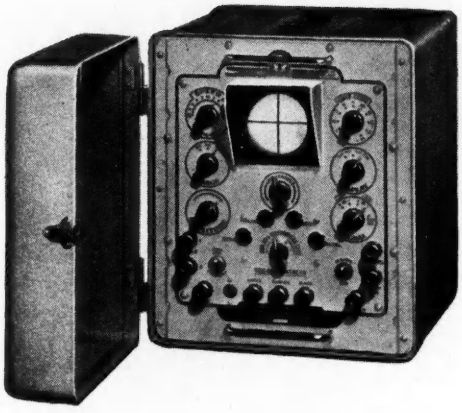

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Sends an automatic test message or characters or reversals at any desired speed and/or percentage of distortion. The CRO has a circular time base for distortion measurements or relay adjustment.

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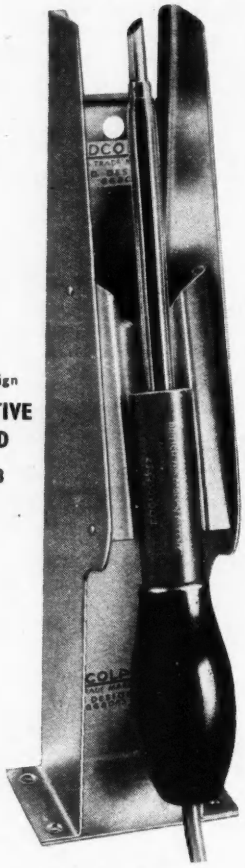

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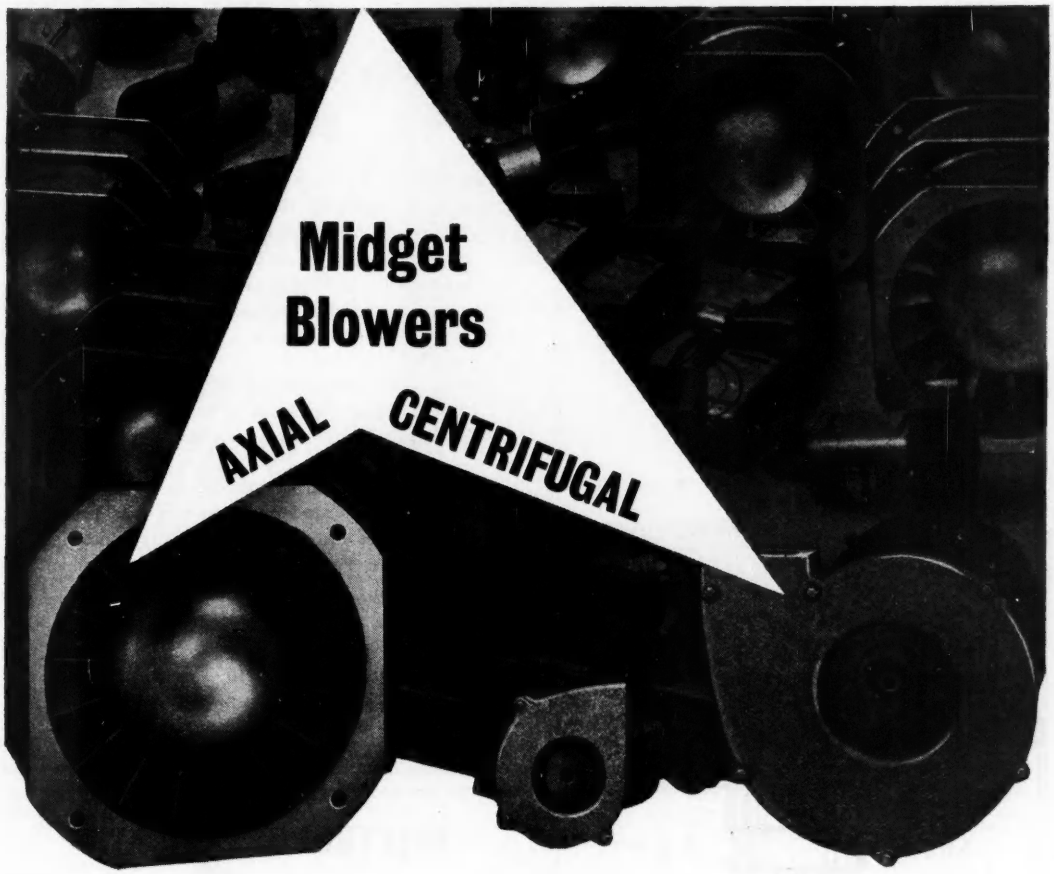

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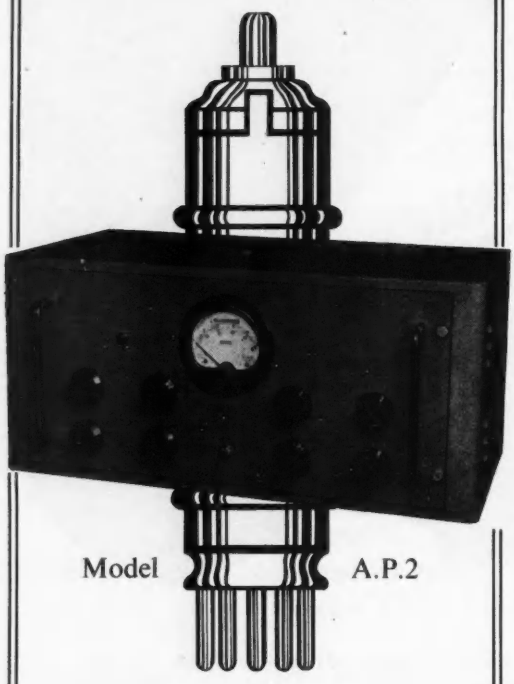

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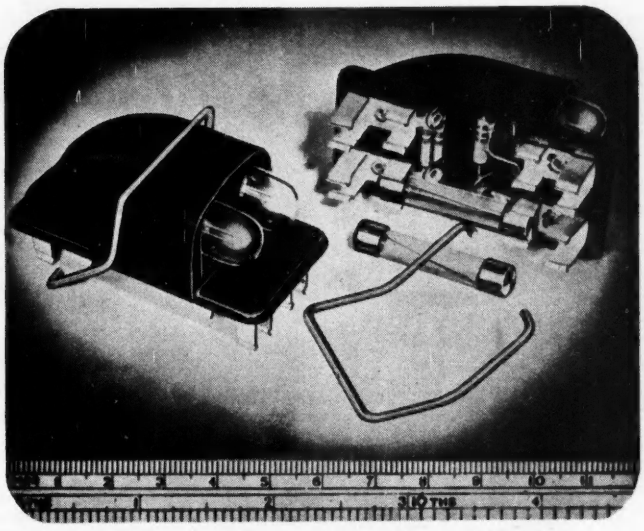
gives visual signal of fuse failure



This is fitted with two bayonet cap neon lamps with their associated resistor network, and is intended to carry a pair of 1¼ in. x ¼ in. fuses of the standard glass or H.R.C. types.

The lamps are designed *to go out on a fuse failure;* it has been said that it would be more convenient if the lamps were to light, but engineers designing critical and important equipment will not countenance such an arrangement where there would be no indication in the event of a lamp failure, whereas now the worst that can happen is for an apparent "fuse failure" signal when no such failure has occurred.

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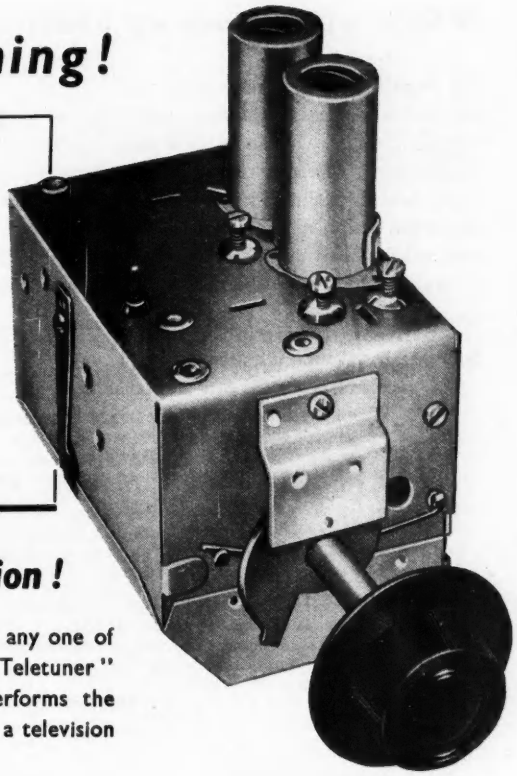

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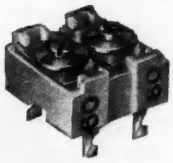

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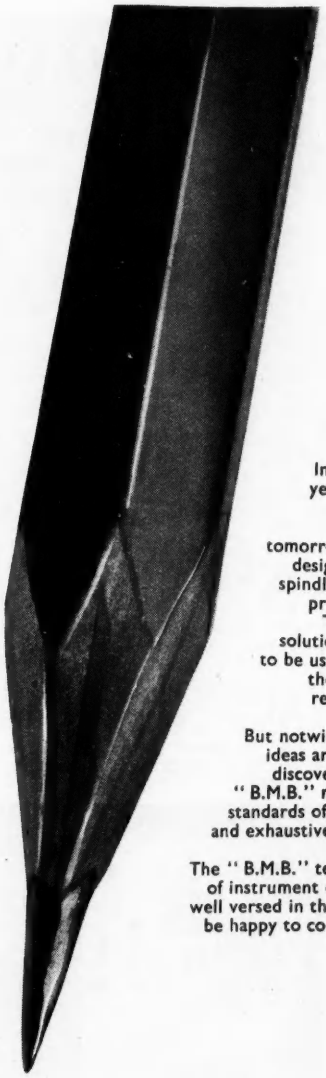

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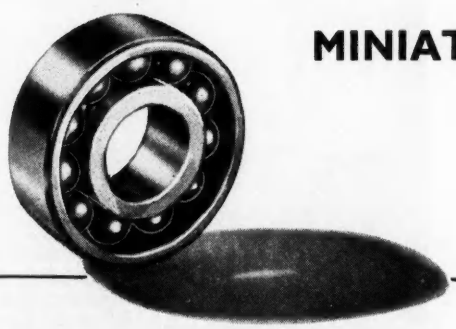

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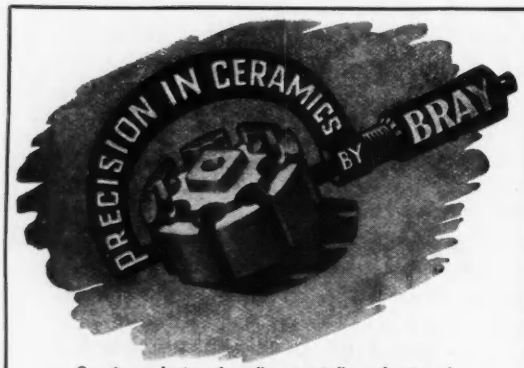

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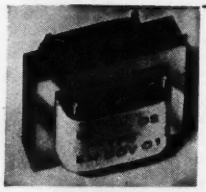

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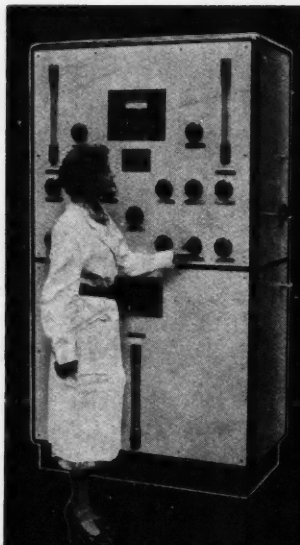

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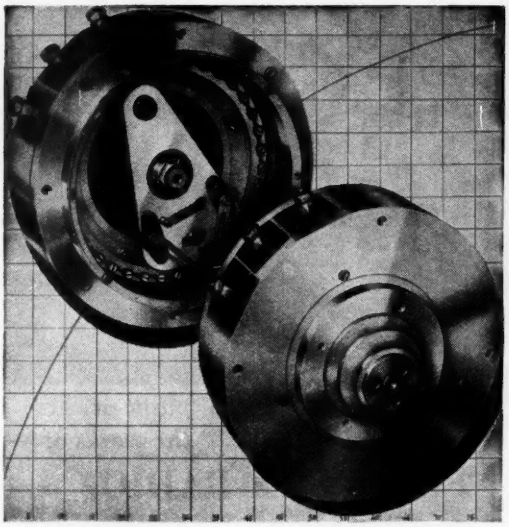

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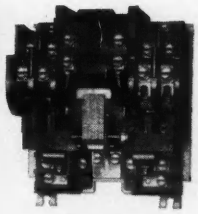

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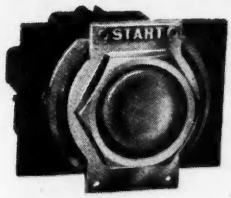

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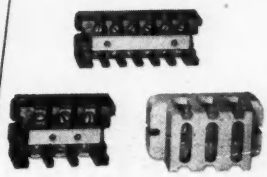

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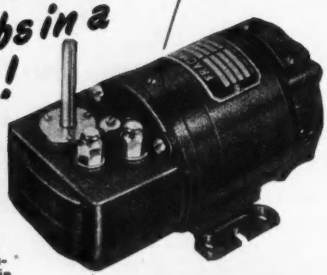

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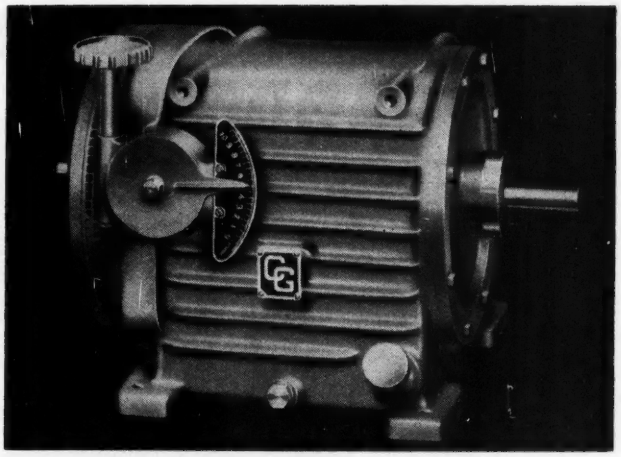

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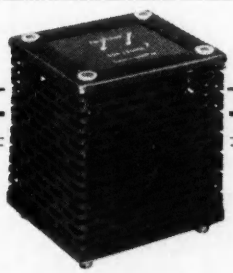

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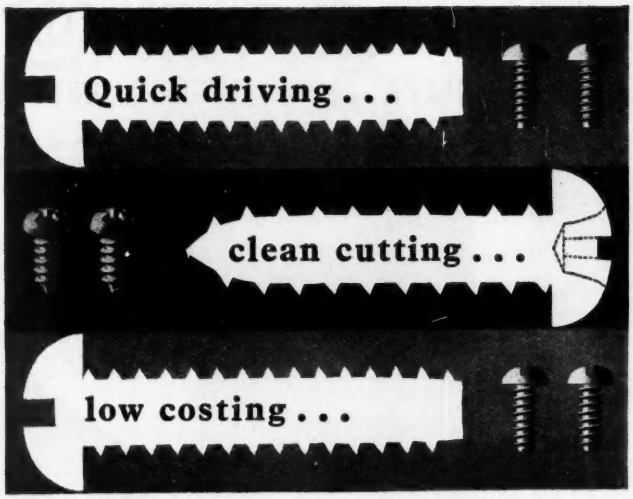

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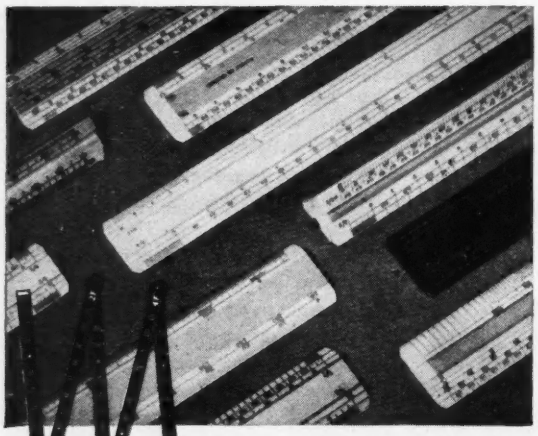

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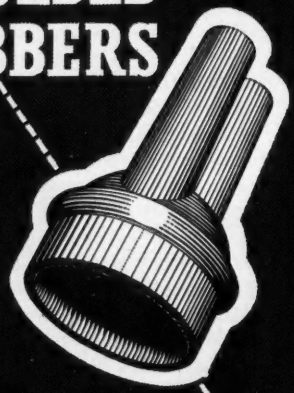

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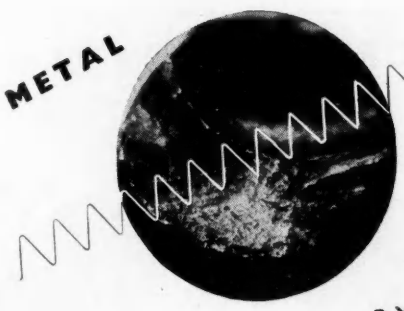

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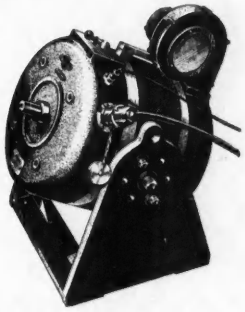

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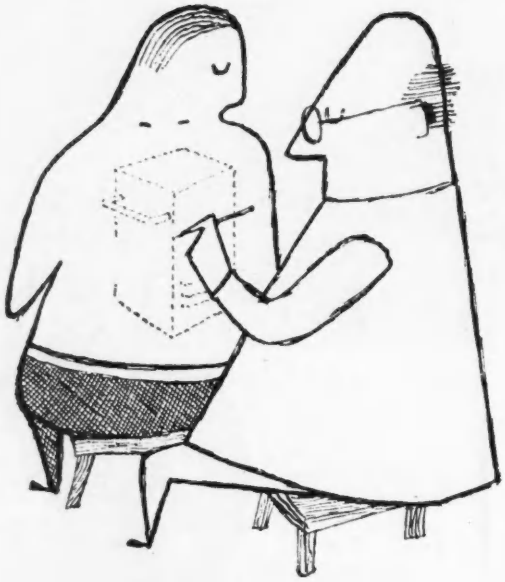

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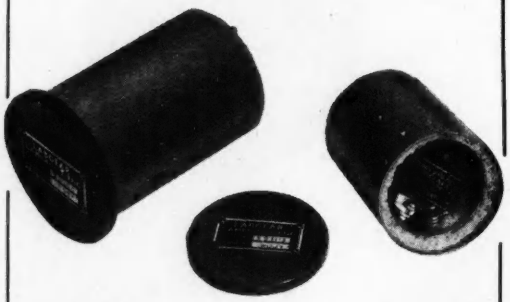

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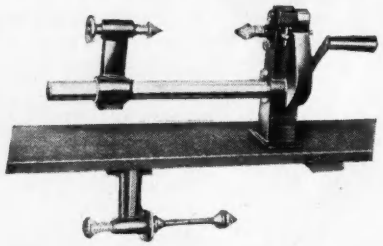

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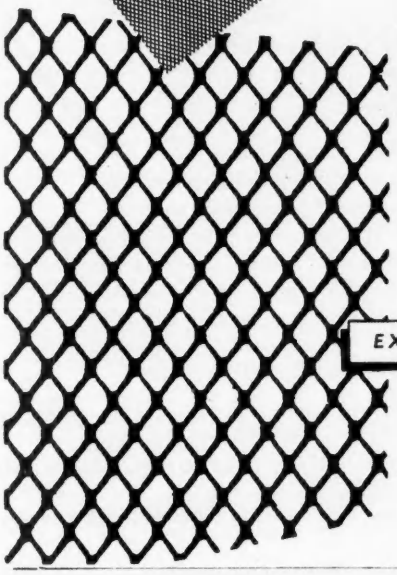

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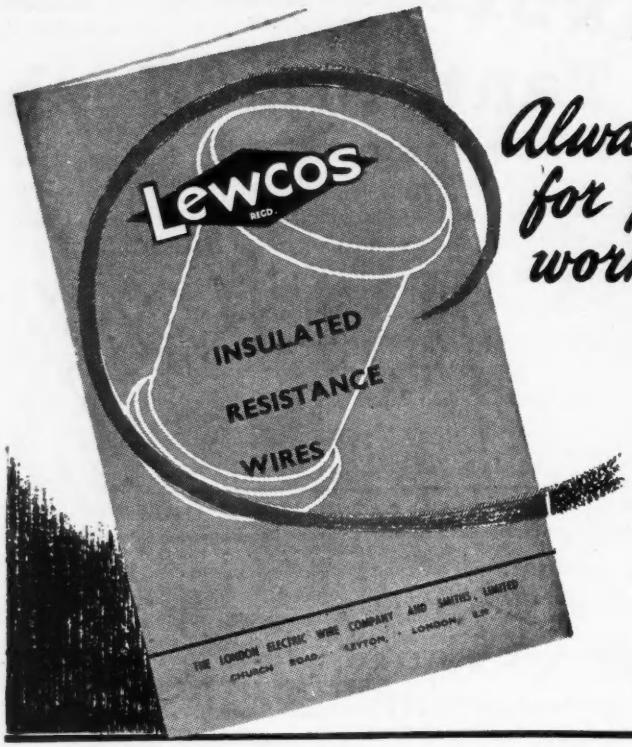

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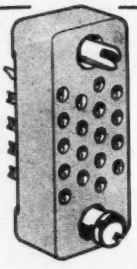
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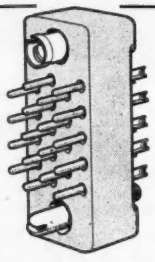
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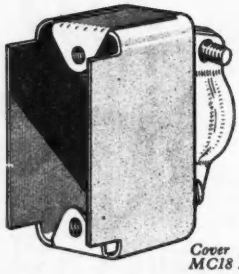
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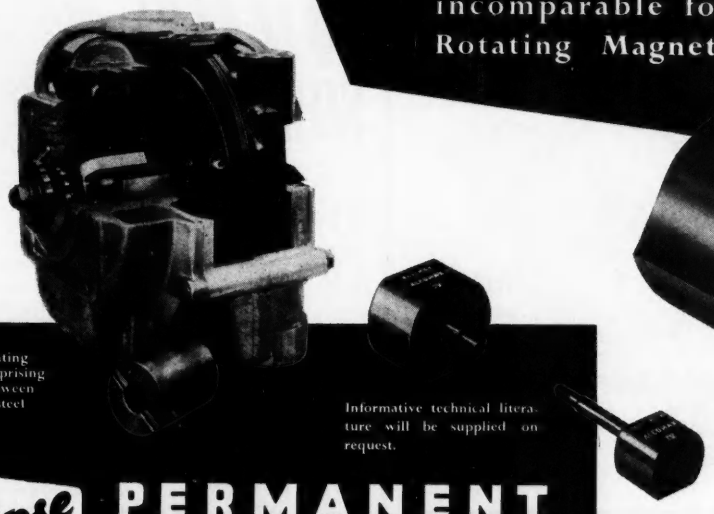

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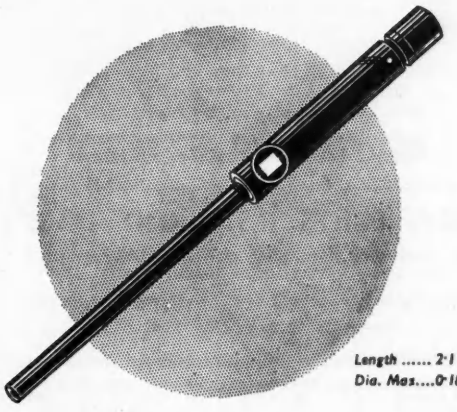

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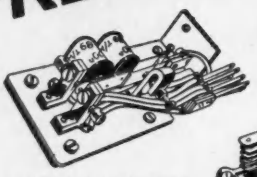

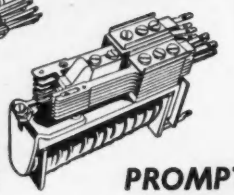

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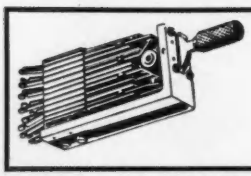

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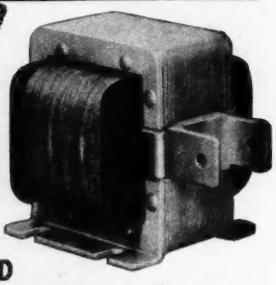

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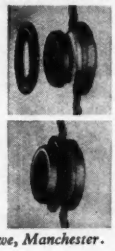

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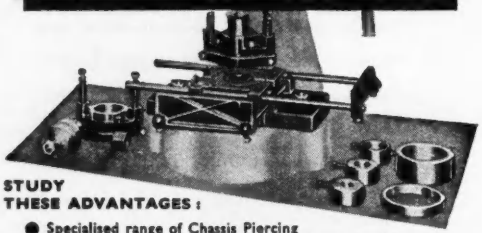

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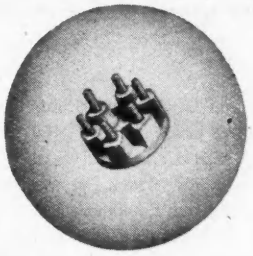

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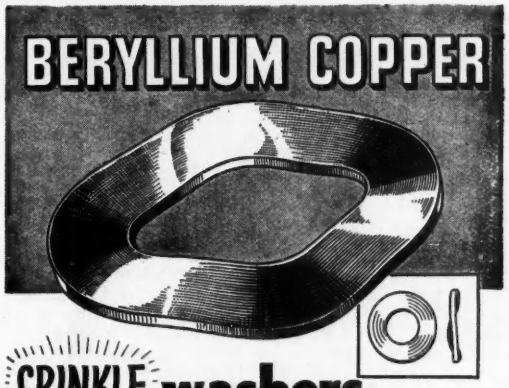

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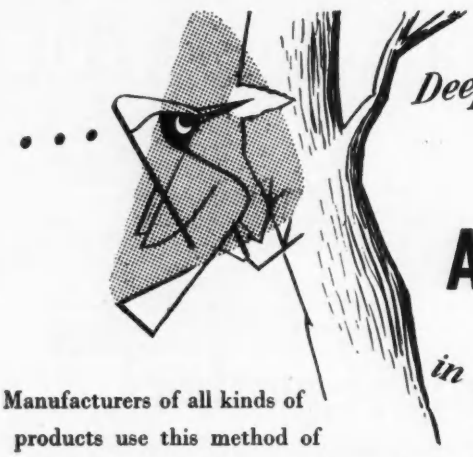

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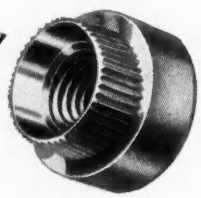

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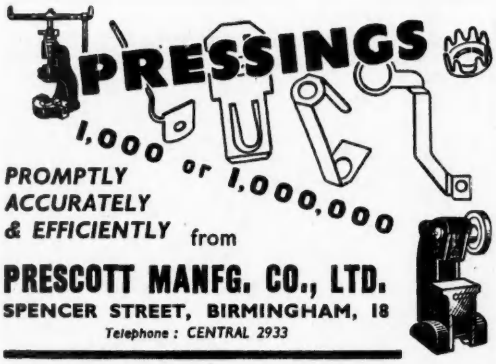

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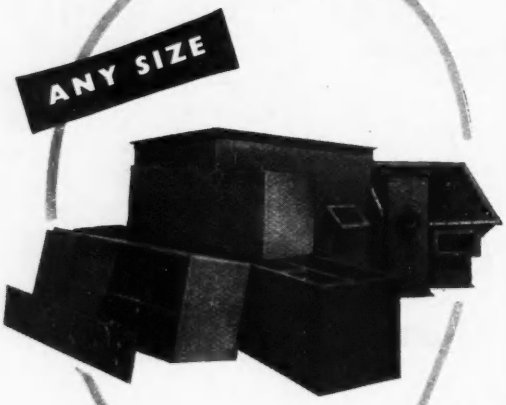

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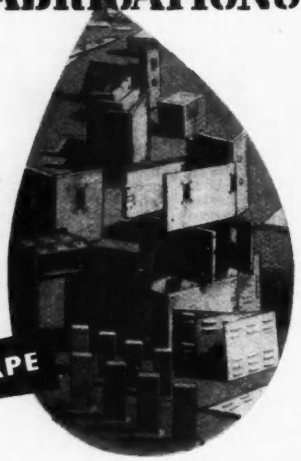

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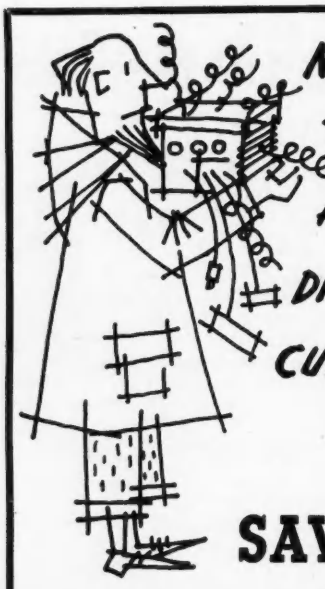

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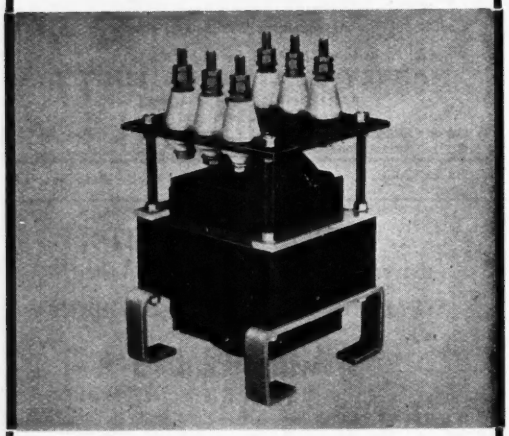

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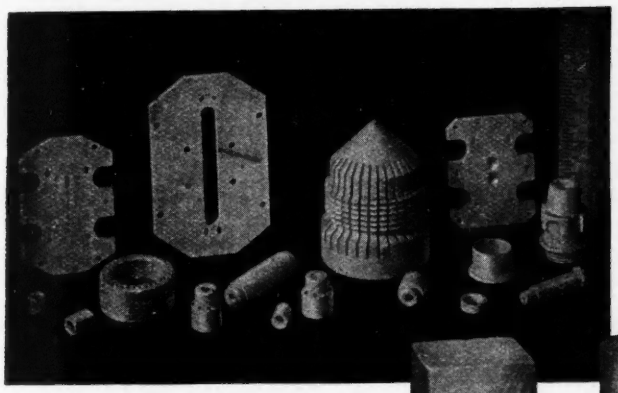

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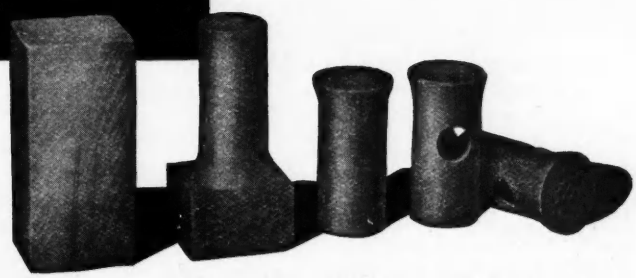

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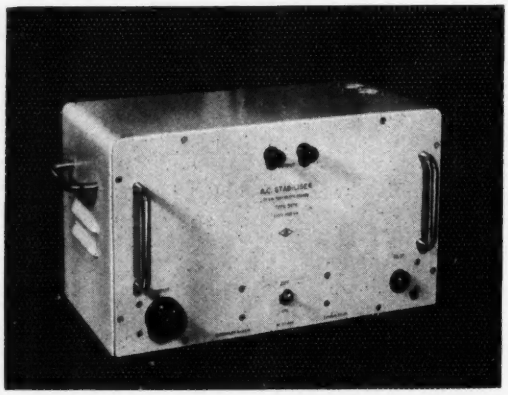

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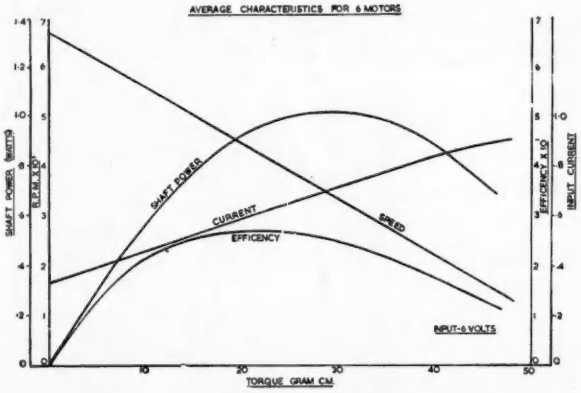

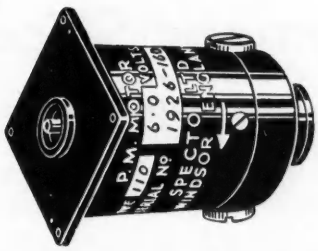

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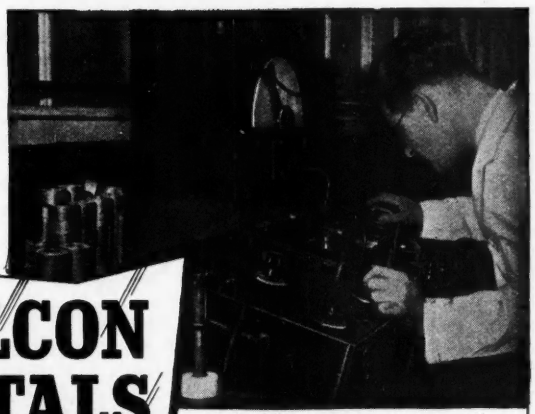

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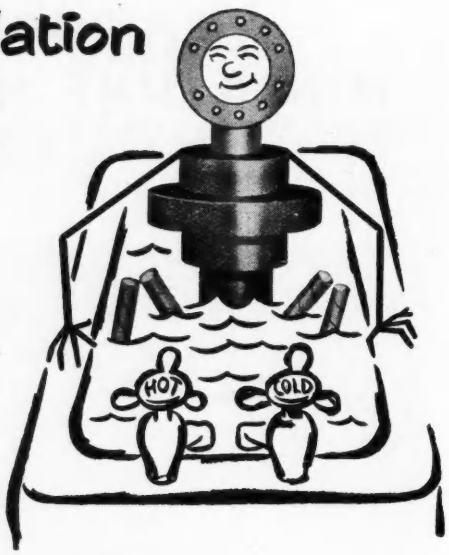

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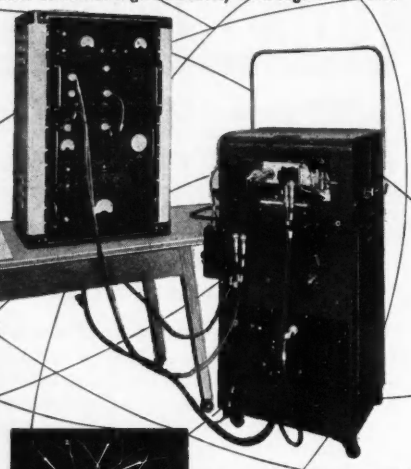

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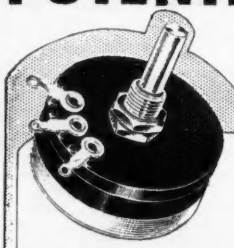

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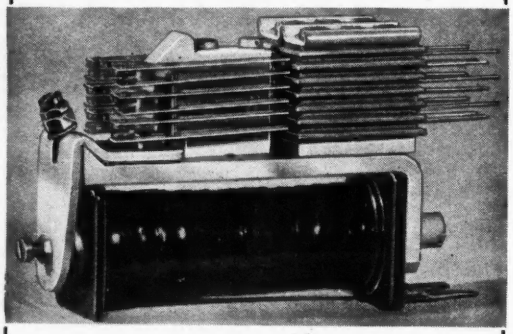

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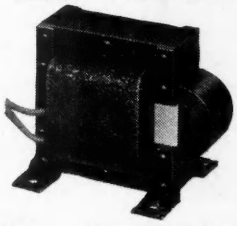

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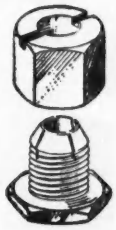

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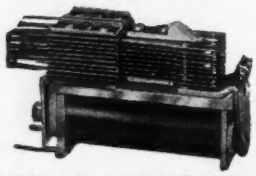

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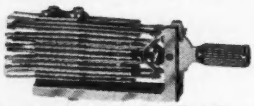

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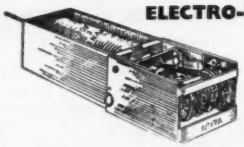

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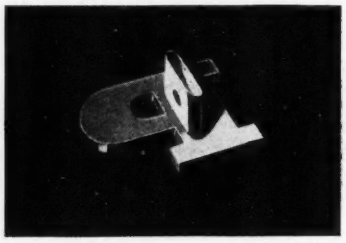

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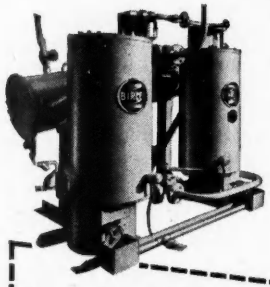

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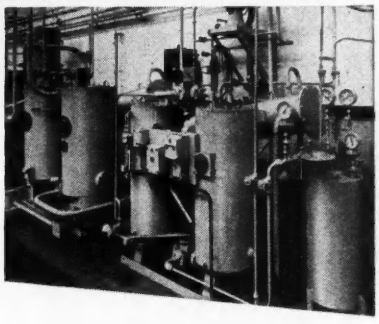

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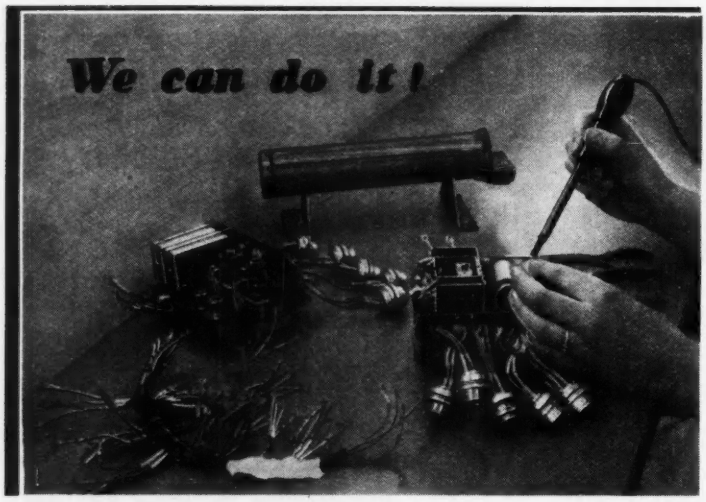

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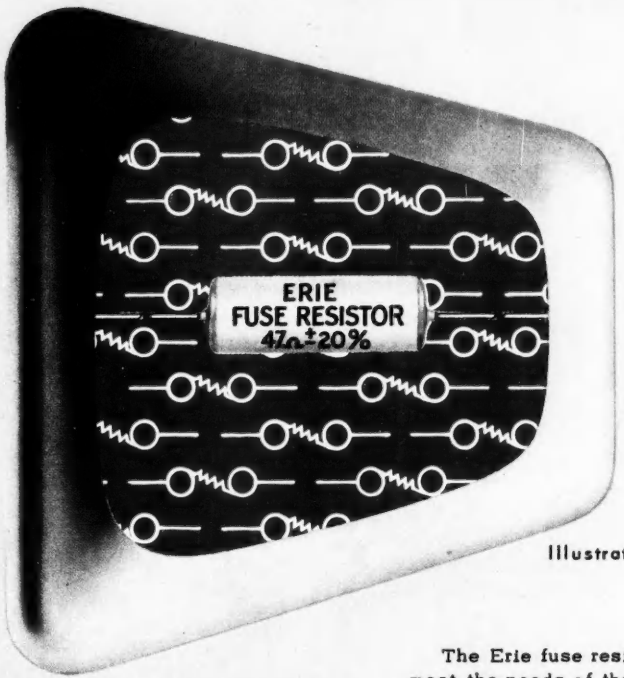

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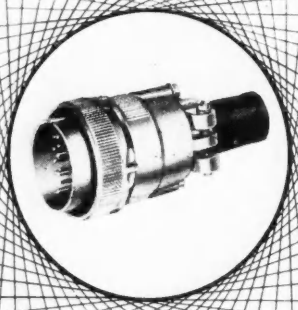

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